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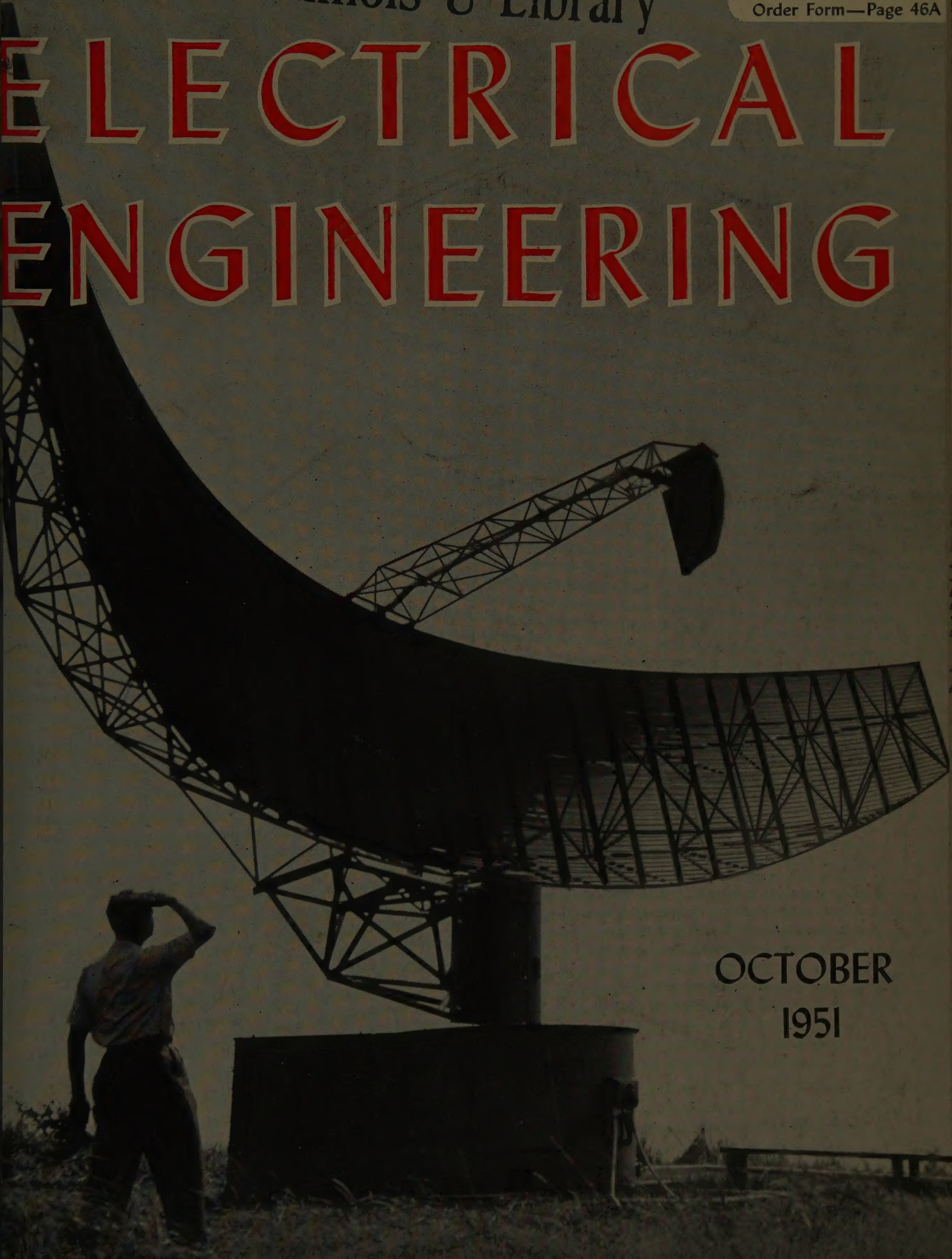
ELECTRICAL ENGINEERING



OCTOBER
1951

FALL GENERAL MEETING, CLEVELAND, OHIO, OCTOBER 22-26, 1951

EXCITING CURRENT
Reduced 50%
WITH THE NEW Curvacore TRANSFORMER

1. EFFICIENT CORE AND COIL ASSEMBLY

The *Curvacore* distribution transformer has high electrical efficiency and low operating cost. It's designed with a wound core made up of cold rolled oriented steel with high flux carrying capacity and low hysteresis loss. Improved coil design offers a more balanced arrangement of core steel to copper. Increased cooling area within windings keeps copper-to-oil gradient low.

Now, you get these added benefits:

1. Exciting current reduced 50%
2. Better ratio of losses
3. Regulation improved 15%
4. Thermal capacity improved
5. Size and weight reduced 15%.

The *Curvacore* distribution transformer is a good investment because its performance will save you money on your system. You get top performance for every dollar you spend.

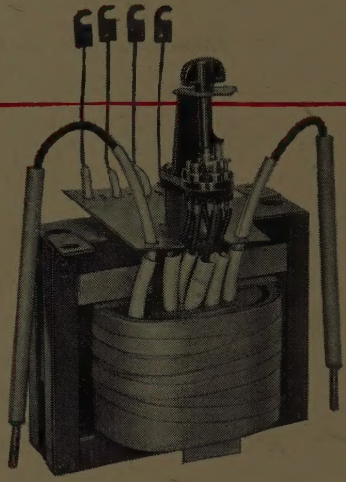
2. EXACTING FINISH EXTENDS TANK LIFE

Formed from heavy gage steel, the *Curvacore* transformer tank is exceptionally strong and completely tight. Tank joints are machine welded to insure permanent protection against leaks and then pressure tested. Tanks are *Spra-Bonderized* and then painted with three coats of alkyd-resinous paint . . . each separately baked on. Previous to shipping, the completely assembled transformer is tested for oil tightness on a machine that tips it toward an inverted position.

Curvacore transformers are now being built in ratings 25 kva and lower. Soon higher ratings will be available.

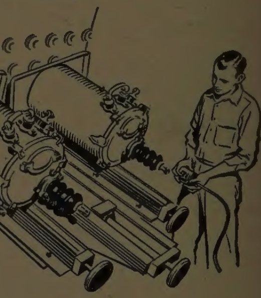
For more information on *Curvacore* distribution transformers, see your local A-C representative. Or write Allis-Chalmers, Milwaukee 1, Wis. A-3413

Curvacore is an Allis-Chalmers trademark.



New internally operated tap changer has handle and position indicating dial plate above the level of the oil.

Special treatment makes surfaces resistant to industrial and humid atmospheres and salt spray.



Gasket seals are thoroughly tested on the tilt table.

Curvacore
TRANSFORMERS

ALLIS-CHALMERS

ELECTRICAL ENGINEERING

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OCTOBER
1951

The Cover: The world's largest commercial type radar antenna is shown. Built for the port of Le Havre, France, the antenna, 41 feet wide and weighing approximately 10,000 pounds, produces a beam width of only 42 minutes and has a power gain of approximately 10,000. See story in Current Interest on page 939.
Raytheon Manufacturing Company photo

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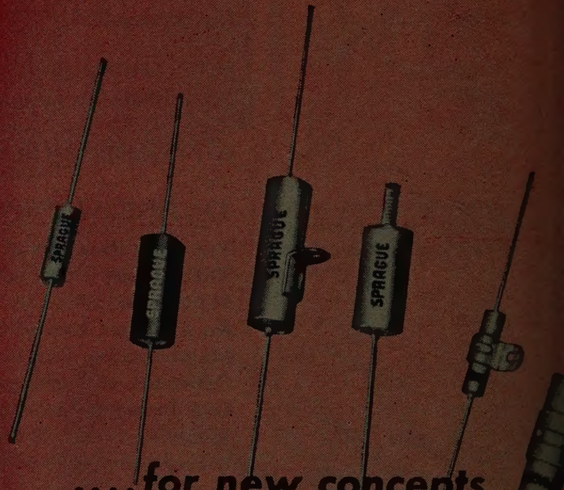
Ahead of and beyond JAN...

Sprague has developed many new ways to reduce size and weight and to improve the high-temperature performance of components

Joint Army and Navy component specifications were never meant to limit engineering progress—and, with Sprague, they most certainly haven't!

The extent of what has been achieved is no better indicated than by the fact that much of Sprague's vast military-use production is based on capacitors, wire-wound resistors and high-temperature wire insulation for which no standard JAN specifications yet exist! These are, in effect, super-JAN—fully approved via waivers to the equipment manufacturers. Such components are being produced and used in ever increasing quantities.

If your problem is one that can be solved by smaller, lighter components or by better elevated temperature performance, chances are excellent that a Sprague application engineer can help you.



....for new concepts of equipment design

Typical of Sprague engineering progress ahead of and beyond JAN limits are these famous subminiature, hermetically-sealed, metal-encased paper capacitors. Far smaller than equivalent JAN styles and available in types for 85°C. and 125°C. operation, these capacitors have helped make possible a long list of military electronic equipment, which never could have met size and weight limitations prior to the development of these capacitors. Sprague Bulletin 213-B gives full technical data.

SPRAGUE

PIONEERS IN ELECTRIC
AND ELECTRONIC DEVELOPMENT

SPRAGUE ELECTRIC COMPANY • NORTH ADAMS, MASSACHUSETTS

HIGHLIGHTS........

Electrical Communication and the Caribbean. Being at once a means and an object of national defense, the web of communication networks which link us with our southern neighbors is a matter of great concern. Mr. I. S. Coggeshall, an expert in the field of international communications, describes the routes and facilities of this web as they exist today, and offers an appraisal of the value of these communications both in peacetime and in war (*pages 847–51*).

Control of Anesthesia. Electric waves, or electroencephalograms, originating in the brain have been found to be a reliable index of the depth of anesthesia of a patient. These waves are used as a control source for a feedback network which applies anesthesia, so that the anesthetized patient himself controls the rate at which anesthetic is administered. This circuit minimizes the time delay and human error of present manual systems (*pages 852–55*).

Development of a Pumpless Ignitron. Improved techniques for detecting small vacuum leaks now make possible a large-capacity sealed ignitron using no vacuum pumps. Actual operating experience indicates that these ignitrons eventually will replace pumped rectifiers (*pages 855–58*).

Hydroelectric Power and the Columbia River. Unique conditions of the Columbia River Basin make it possible to use storage space both for flood control and power generation with equal effectiveness (*pages 861–65*).

Electric Shock. The author reviews the literature which has been written on the subject of electric shock, discusses animal experimentation and actual field cases dealing with the problem, and draws conclusions from his study (*pages 871–76*).

Economic Factors of Dieselization and Electrification. When it comes to the choice between diesel-electric and central-station electric railways, a number of economic factors must be considered. Conditions existing in the United States tend to favor diesel-electric locomotion, while other countries have equally good reason for choosing electric power (*pages 867–69*).

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Determining Reserve Capacity. Allocating the reserve savings derived from interconnecting two power systems is investigated by Professor Calabrese, whose approach is by way of probability methods. This month's article deals with the effect of interconnecting two systems on the degree of service reliability of each system, assuming straight-line daily maximum load duration. By this assumption the optimum interconnection capacity also is determined (*pages 876–78*).

Terminal Equipment for the Microwave Relay. Converting the message frequencies to the 70-megacycle intermediate frequencies and recovering them is the function of the frequency-modulation terminal equipment of the Bell System's cross-country microwave relay. Among the many problems of the design was the stringent linearity requirement which was necessary to enable as many as 16 pairs of terminals to operate in tandem for long-haul hookups (*page 880–83*).

Trends in Vertical Water Wheel Generator Design. The last two decades have seen some definite trends and marked improvement in the design of hydroelectric machinery. The high cost of such installations has led the emphasis toward high reliability to insure long life and low maintenance costs, and toward smaller and less costly machines (*pages 887–92*).

An Induction Galvanometer. By injecting an alternating component of flux into the permanent field flux of a movable-coil instrument structure, the device becomes a highly sensitive d-c to a-c converter. At normal zero-center position, no alternating voltage is induced in the coil; but if a small direct current deflects the coil, the alternating flux linkages increase proportionally to the deflection, thus causing an induced alternating voltage in the coil. This may be extracted for amplification (*pages 893–98*).

Power-Line Synchronization Problems in Television. Since hum can be removed even though the camera is not power-line synchronized, the practice of power-line synchronization is reviewed from the standpoint of hum and stability. The investigation leads to the conclusion that power-line synchronization may cause more trouble than it eliminates (*pages 903–04*).

Symbols and Terms for Feedback Control. The early acceptance of a unified symbolism and terminology will promote ease of communication between engineers in related fields and between a company and its customers, and will permit the writing of specifications for equipment that can be understood by workers in all of the related fields (*pages 905–09*).

AIEE Proceedings

Order forms for current AIEE *Proceedings* have been published in *Electrical Engineering* as listed below. Each section of AIEE *Proceedings* contains the full, formal text of a technical program paper, including discussion, if any, as it will appear in the annual volume of AIEE *Transactions.*

AIEE *Proceedings* are an interim membership service, issued in accordance with the revised publication policy that became effective January 1947 (*EE, Dec '46, pp 567–8; Jan '47, pp 82–3*). They are available to AIEE Student members, Associates, Members, and Fellows only.

All technical papers issued as AIEE *Proceedings* will appear in *Electrical Engineering* in abbreviated form.

Location of Order Forms	Meetings Covered
Nov '50, p 44A	Middle Eastern District Fall General
Mar '51, p 35A	Winter General
Jul '51, p 23A	Southern District North Eastern District Great Lakes District Summer General

Minimum Surface Leakage Distance. Increasing compactness of electric power equipment requires a more thorough knowledge of the properties and limitations of insulating materials. Reported in this issue are the results of a study of the minimum safe leakage distances for d-c systems. The purpose of the study was to determine and evaluate the factors which affect leakage distance so that reliable values for minimum distances can be established (*pages 910–14*).

AIEE Technical Subcommittees. Over 200 technical subcommittees of the Institute and their personnel are listed in this issue (*pages 929–38*). This is in completion of the list in the September issue (*EE, Sep '50, pp 833–38*), which presented Institute officers and the personnel of the main general and technical committees.

Membership in the American Institute of Electrical Engineers, including a subscription to this publication, is open to most electrical engineers. Complete information as to the membership grades, qualifications, and fees may be obtained from Mr. H. H. Henline, Secretary, 33 West 39th Street, New York 18, N. Y.

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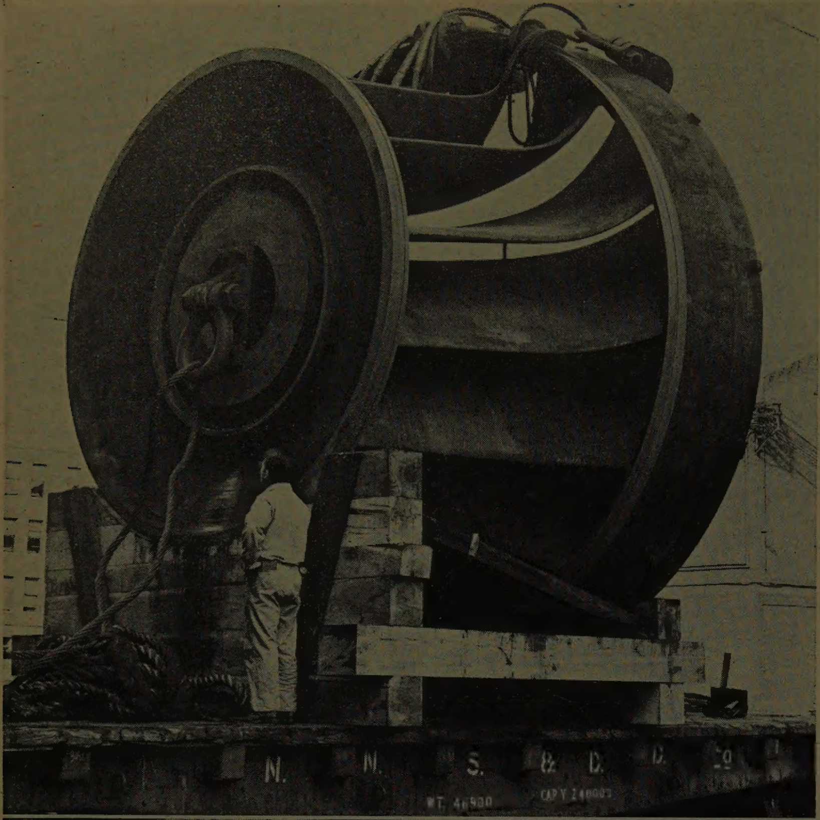
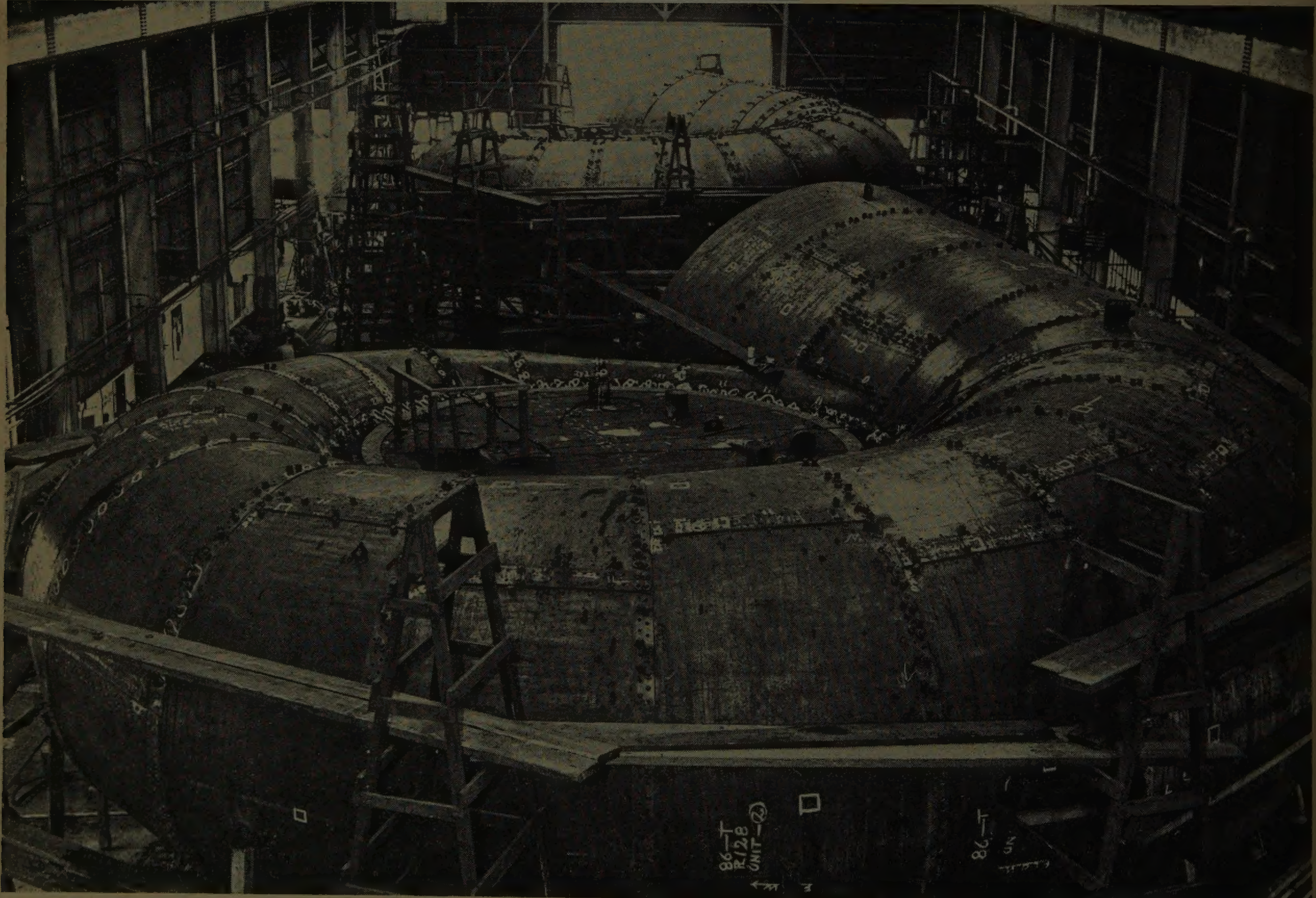


Over Eight Million Horsepower

The Newport News Shipbuilding and Dry Dock Company has received orders for the building of hydraulic turbines aggregating an output of 8,150,000 horsepower.

Left: Runner for the Buggs Island Development

Below: Assembly of spiral casings for the C. J. Strike Development



NEWPORT NEWS
SHIPBUILDING AND DRY DOCK COMPANY
Newport News, Virginia

Electrical Communication and the Caribbean

I. S. COGGESHALL
FELLOW AIEE

AS THE UNITED STATES strengthens itself to bring into balance its foreign obligations and its power to discharge them, the total mobilization of its resources includes bringing transportation and electrical communication organizations into the direct orbit of the military effort.

The interreliance of Government and the private companies spotlights the fact that electrical communication, like sea-borne and air-borne commerce, is at once an object and a means of national defense.

This is quite as true of the lines of communication which cross the Gulf of Mexico and the entire Caribbean Sea area as of those which cross the North Atlantic or the Pacific Oceans. Regardless of how military emphasis shifts between Europe and the Orient, the integrity of the Western Hemisphere is a matter of concern to the people of the United States. Since the 1870's, electrical communication has made it possible for the United States both to formulate and to exercise its protective obligations.

Vital to the Western Hemisphere is the vast network of telephone and telegraph channels which joins together the Americas. In peacetime it is an essential medium of cultural exchange; in time of war it is a first line of defense for the western democracies.

The laying of the first Caribbean cable from Punta Rassa through Key West to Havana with American capital took place in 1866, the same year as the successful laying of the first transatlantic cables.[1] Many cables, including several telephone cables, have been laid in the Gulf and the Caribbean since those early days. Considered together with the comparatively new radio circuits, in the establishment of which the United States Navy and the United Fruit Company pioneered, a vast web of communication facilities has been created that overlays the area as completely as the steamship and airplane routes which serve it.

These lines of electrical communication must be protected from encroachment, for they themselves help protect the entire hemisphere from encroachment. Not only is local Caribbean telegraph traffic at stake, but the larger volume of that between the United States and the whole of South America. The main line of the All America cables between New York and South America crosses the Caribbean between Fisherman's Point (Guantanamo, Cuba) and Panama; Western Union's New York—South American cable lies in the Caribbean between Miami and Barbados; and a substantial portion of the radiotelegraph and radiotelephone traffic between North America and the Latin Americas is transmitted from or received at stations in Florida and Louisiana.

The Caribbean is the Americas' *Mare Nostrum*—Our Sea—as the ancient European cartographers were wont to call the Mediterranean. The control of communications in that area must continue to be in hands friendly to the Americas.

The military importance of the Caribbean link between the United States and Brazil is succinctly stated by Lippmann[2] who, after pointing out that the passive defense of the Caribbean by means of the bases extending from Guantanamo to Trinidad is inadequate to protect the Hemisphere defense line running from Cape Horn to Iceland, says: "On the approaches to South America, the maintenance of strong sea and air bases on the bulge of Brazil is essential. The strategic defense of the whole South American Continent as it faces the Atlantic is dependent upon sea and air communications (across the Caribbean)." He then completes the picture by showing that the United States must be prepared to parry enemy thrusts from all quarters, whether pointed at the North Atlantic seaboard from the direction of the North Sea and Gibraltar, or directed against Brazil from Cape Verdes to the Cape of Good Hope and the Straits of Magellan.

CARIBBEAN COMMUNICATION IN PEACETIME

TECHNOLOGY HAS brought both cable and radiotelegraphy a long way from the days when a cable operator used to sit at a typewriter deciphering the wavy line which his recorder drew upon a moving paper tape, and when radio operators transcribed on typewriters the dot-dash sounds which they heard through earphones.[3]

The terminal operations of radiotelegraphy and cable operation have reached a common denominator rapidly since the end of World War II. Differences in transmission, whether by Morse or 5-unit code, are purely technical; both are employed on cables and both are employed in radiotelegraphy, and both can be made to operate printers automatically, at speeds representatively around 50 to 60 words per minute. Together, radio and cable facilities constitute the highroads over which pass the communicated thoughts and intelligence of the Western Hemisphere—as intricate in pattern as the routes of sea and air transportation with which they are interwoven in the manner of warp and woof. American landline telegraph developments set the technological pace for the submarine cables because of the fact that they worked as an entity in end-on operation between large population centers across the seas. After

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Substance of a District Paper, "Florida: Communication Gateway to the Caribbean," presented at the AIEE Southern District Meeting, Miami Beach, Fla., April 11–13, 1951.

I. S. Coggeshall is General Traffic Manager of International Communications, the Western Union Telegraph Company, New York, N. Y., and is President of the Institute of Radio Engineers.

about 1920 it became commonplace to repeater one long cable section into another, the result having been made possible by improvements in relays, signal-shaping networks, and magnifiers. In cable recorder Morse transmission, both the Cable and Wireless and All America Companies[4] developed printers and switching controls for use at the terminals and all points enroute. The joint West Indies-Caribbean system of Western Union and Cable and Wireless, through Miami, Key West, and Havana, is similarly equipped.

On its North Atlantic system, however, Western Union departed from tradition by abandoning Morse with the laying of the first of its loaded cables in 1924; and since that time has converted all its cables to standard 5-unit printers of the type used on its landlines. The advances which made success possible were: the development of the vacuum-tube amplifier to replace the magnifier; development of the arts of signal-shaping and frequency analysis; utilization of brush-driven vibrating circuits for locally filling in, at the receiving station, signals which had been completely attenuated by passage through the cables;[5] a method of mitigating "zero-wander" of received signals; improvement in electric relays; means for increasing the fork-controlled power which could be applied to distributor wheels; automatic turnaround of signaling direction with several repeater stations involved along the cable route, multistage amplifiers to be switched in and out of circuit, stage by stage, and with complex relationships of eastward and westward signal phasing.[6] Solution of these problems in 1924, with the audio-frequency art not yet fully developed, broke new ground in the radio amplifier and carrier-current art, and was the direct result of the cables' drawing upon landline telegraph and telephone laboratories' knowledge.

American commercial radiotelegraphy, with no such landline alliance as pertained in the cable industry, with little control over their foreign correspondents' stations, and beset with difficulties in taming their transmission medium, was far less quickly responsive than the cables to American landline technical progress. When the exigencies of World War II forced the War Department and the United States Navy to look to the domestic telegraph and telephone systems for means of applying printers to military radiotelegraph circuits on a world-wide scale, radio began to draw upon available landline technology. In the telephone company was found the know-how of adapting its overseas radiotelephone to the provision of highly reliable radio teletype operation of long-haul circuits.[7] In the telegraph company was found a quantity of surplus reperforator equipment resulting from the merger of Postal Telegraphs with Western Union, which was suitable for radio's terminal switching problems.[8] In both companies were found co-operative management, engineers, and technicians capable of combining the elements into a practical, efficient world-wide military system.

TELEGRAPH ROUTES AND FACILITIES

Traffic picked up in the United States destined for delivery in Latin America follows the routes which will be described briefly.

Landline Telegraph System. The backbone of the landline telegraph system is the aggregation of circuits which interconnect each of the 15 major switching points in the country with each other.[9] The switching centers at Boston, Philadelphia, Atlanta, Richmond, New Orleans, and Dallas are of predominant importance to the Latin American picture; and these, plus the Western Union offices in New York, Miami, and New Orleans, which are directly tied to the various carriers and cables, are the essential landline elements in routes to the Caribbean and beyond.

The landline system is so contrived that, in general, a tributary office which originates an outbound international message is the first and only office involved in a keyboard operation in its preparation and subsequent handling until it is in the hands of an international carrier.

The nation-wide network is set up everywhere on essentially the same basis—an automatic electrical switching operation through the first of two switching offices in tandem, a plug-in or push-button operation through the second, and only two switches en route from office of origin to the international carrier at destination. This makes for rapid, accurate service, with little human rehandling.

Concurrently with the installation of the country-wide system of switching centers, Western Union put the greater portion of its intercity trunk circuits into frequency-modulated carrier[10] in multipair overhead and underground cable. Frequency-modulated carrier has added greatly to the stability and flexibility of its circuits; the use of cable has made them highly stormproof and weatherproof.

RCA Communications and All America give a complete coverage of the Caribbean area from New York (beyond the scope of this article), and Globe Wireless and Press Wireless a somewhat more restricted service from New York. Their "lines," of course, cut over or under the Caribbean. All America has a cable connection from Western Union in Miami to All America in Havana.

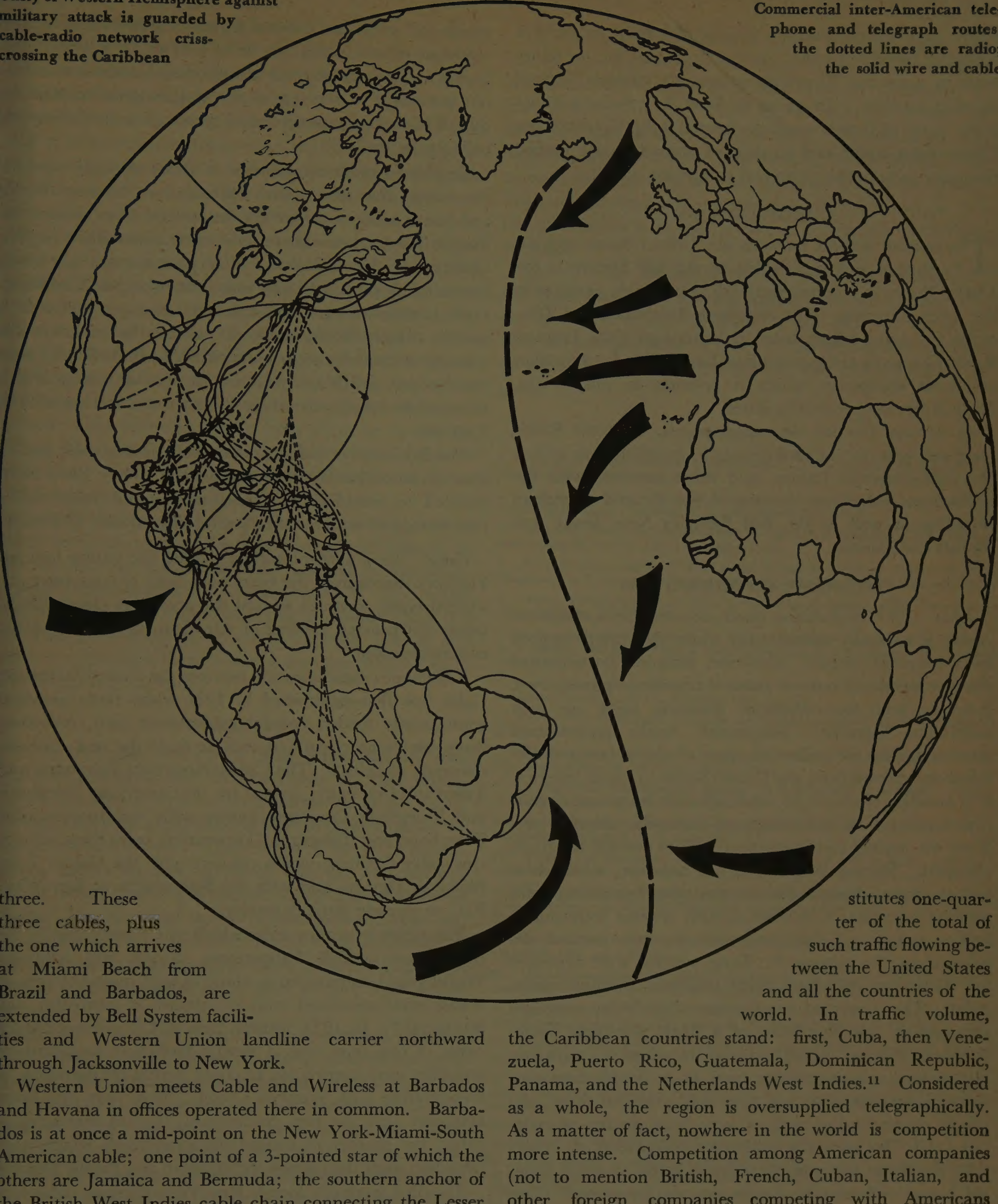
Tropical Radio Telegraph System. Tropical Radio has a receiving site and transmitter control station at Fort Lauderdale, Fla., and two duplex teleprinter connections with Western Union, Miami, to tie the two systems together as an operating unit. The radio transmitters proper, and the antenna systems to which they may be switched by remote control from Fort Lauderdale, are located at Ojus. A 1-way 12-channel ultrahigh-frequency radio beam serves the dual purpose of modulating the Ojus transmitters and switching them to suitable directive transmitting antennas.

The New Orleans station of Tropical is at Harahan, La., and its Boston station is at Hingham, Mass. During 1951, plans will be consummated to convert Tropical's system throughout the Caribbean area to stop-start teleprinter operation. Its station at Panama City will become a reperforator station of modern type.

Western Union Cable System. Western Union owns a cable between Miami Beach and Key West, and leases from the Bell System a facility between Miami and Key West upon which it places a telegraph carrier system. A sufficient number of circuits is derived to take care of Key West's domestic telegraph requirements and to feed the Key West-Havana telegraph cables, of which there are

Unity of Western Hemisphere against military attack is guarded by cable-radio network criss-crossing the Caribbean

Commercial inter-American telephone and telegraph routes: the dotted lines are radio; the solid wire and cable



three. These three cables, plus the one which arrives at Miami Beach from Brazil and Barbados, are extended by Bell System facilities and Western Union landline carrier northward through Jacksonville to New York.

Western Union meets Cable and Wireless at Barbados and Havana in offices operated there in common. Barbados is at once a mid-point on the New York-Miami-South American cable; one point of a 3-pointed star of which the others are Jamaica and Bermuda; the southern anchor of the British West Indies cable chain connecting the Lesser Antilles to Havana, Miami, and New York; and finally the site of a radiotelegraph installation that serves the West Indies, reaches up to Montreal and London, and down to Lima, Peru, to meet the British trans-Andean cable system.

COMPETITION AND MERGER

INTERNATIONAL COMMERCIAL telegraph traffic to and from Central and South America and the West Indies constitutes one-quarter of the total of such traffic flowing between the United States and all the countries of the world. In traffic volume, the Caribbean countries stand: first, Cuba, then Venezuela, Puerto Rico, Guatemala, Dominican Republic, Panama, and the Netherlands West Indies.[11] Considered as a whole, the region is oversupplied telegraphically. As a matter of fact, nowhere in the world is competition more intense. Competition among American companies (not to mention British, French, Cuban, Italian, and other foreign companies competing with Americans for traffic) reaches the point of absurdity in the case of Cuba, where five American radiotelegraph and two cable companies wastefully compete for the limited traffic available.

Since this condition prevails also in other regions of the world, the larger international telegraph carriers and many thinkers in the executive and legislative branches of the Government believe that competition in the international telegraph industry has reached the point of destructiveness where permissive legislation should be passed to make a regulated merger possible. It is difficult now for our diplomats to press one American company's interests without injuring another. To quote de Wolf:[12] "From a diplomatic point of view it would be helpful if the United States Government could lend its support abroad to one unified company rather than to several competing ones."

RADIOTELEPHONY

Telephone service between the United States and the Caribbean area is provided by the Bell System in the United States in co-operation with appropriate agencies in the other countries. The American Telephone and Telegraph Company utilizes space in the stations of the Tropical Radio Company at Ojus and Fort Lauderdale for the radiotelephone equipment which it operates in this service. Cuba is served via cable facilities.

At certain Central American points, Tropical Radio owns and operates the radiotelephone installation as well as the radiotelegraph station, and there connects with the government telephone systems of the Central American republics as well as the Bell System's New Jersey and Florida installations.

TECHNICAL CONSIDERATIONS

Radio. The modulation band required for a telephone circuit is naturally considerably wider than that required for a telegraph circuit. However, technical development of single side-band systems makes it possible to provide two, three, or even four telephone channels, using one such wide-band frequency assignment. Such multichannel systems are in use today on most of the overseas radiotelephone circuits from the United States to Latin America. It is possible, of course, to subdivide such telephone circuits into a number of radiotelegraph channels, although this is not the normal and economical way to provide telegraph channels. During World War II, however, when there was an urgent demand for overseas telegraph channels for military purposes, a number of such systems were put in service, using a 2-tone frequency diversity method developed for the purpose.[13] These systems were arranged for teleprinter operation using standard landline equipment. They provided a maximum of six 2-way telegraph channels on one side band of a single side-band radiotelephone system. Under adverse transmission conditions, this system was sometimes used as a double-frequency diversity arrangement, and thus only provided three telegraph channels, but with a very high degree of reliability.[14,15] To meet the military requirements on routes with somewhat less concentrations of traffic, a single channel 2-tone radioteletype system was also developed. This had very extensive use throughout the war and has continued to be of great importance in both military and civilian overseas services.

Need by the armed services was the driving force behind some of these developments, as was the case in the application of Western Union's standard 4-channel multiplex equipment to Navy Radio in the Pacific[16] area during World War II.

These contributions to the radio art by the landline telegraph and telephone carriers represent only part of the tremendous efforts which are being exerted by private companies and government telegraph administrations throughout the world to accomplish the technological miracle required to make an overcrowded spectrum serve the myriad calls for its use.

Caribbean radio transmission is above average; and for the reason that north-south transmissions between North and South America do not cut the auroral zones around the magnetic poles, hemisphere radio communication is high in quality and dependability. This phenomenon has given rise to many proposals, and some action, to use Caribbean radio installations as "tropical belt" repeater points in a pattern which would make it possible for radio routes crossing auroral zones to be avoided.[17] Both RCA Communications and Mackay Radio use a modification of this principle by taking advantage of the neutral territoriality of Tangiers.

The British have found similar usefulness in their possession of Barbados in the Caribbean.[18] They have been enabled to establish an exceedingly useful joint cable-radiotelegraph station there, affording traffic flexibility.

Cable. To a rather marked degree the cables laid off Florida's shores over the years have been of constantly advanced types, so much so that the area may claim title to being the proving ground of American progress in cable communication.

Telephone communication between the United States and Cuba was first established in 1921 when three identical continuously loaded coaxial cables were laid, providing three telephone circuits as well as three d-c and nine a-c telegraph circuits.[19] The Cuban American Telephone and Telegraph Company, owned by the American Telephone and Telegraph Company jointly with the International Telephone and Telegraph Corporation, owns these submarine cable facilities, which connect with the Cuban Telephone at Havana and with the Bell System at Key West, Fla., to provide through service.

The nickel-iron alloy series which was investigated by the predecessor of Bell Laboratories during and following World War I culminated in alloys of high magnetic permeability now associated with the names of permalloy and mu-metal.[20] In 1923, historic tests of 120 miles of loaded cable of this type with a newly developed vacuum-tube amplifier were carried out in ocean depths off Bermuda, in co-operation with Western Union. Next year, the latter company laid the first continuously loaded transatlantic cable, the pioneer of several thousand miles which have been laid since then across the Atlantic and Pacific Oceans.

The Bell System's fourth Key West-Havana cable was laid in 1930,[21] and its novel features were copied by telephone administrations throughout the world. The cable employed synthetic paragutta rather than natural gutta percha as the insulating material. New design of the coaxial conductors made it possible to divide the spectrum by standard carrier frequency division into seven voice-frequency bands, any of which was, of course, adaptable to further frequency subdivision for teletype channels.

In 1949 Western Union's cables between Key West and

avana were equipped with new 2-way carrier equipment
ing frequency modulation.[22] Each of the carriers is
pable of transmitting signals from a 3-channel time-
vision multiplex printing system.

In 1950, following experiments in various parts of the
orld in submerging vacuum-tube amplifiers in cables on
e seabottom, two notable American achievements in this
rection were recorded. One was a cable telegraph re-
eater, sunk in approximately 150 fathoms of water in one
Western Union's transatlantic cable sections off New-
undland;[23] the other the Cuban-American Telephone and
elegraph Company's new pair of cables, of Bell Labora-
ries design, containing three repeaters in each cable,
nk in the straits between Key West and Havana.[24] The
ying of these two cables had been preceded, in 1948, by
e laying of a test length of cable containing one of the
peaters in water up to 2 miles deep off the Bahamas.
ne new cables transmit signals from 12 kc up to 108 kc,
elding 24 voice-frequency channels in each unidirec-
onal cable. Two of the repeaters are nearly a mile be-
w the surface.

Whether these two cables with their repeaters spaced at
-mile intervals presage the first transatlantic telephone
ble, no one can say for certain. Buckley prophetically
w such a cable in his 1942 Kelvin Lecture.[25] The British
able and Wireless is said to be laying a 600-mile cable this
ar with five repeaters in series between Lisbon and
adeira, to produce three 2-way voice channels and eight
way teleprinter circuits.

CONCLUSION

HE WIRE, radio, and ocean cable telegraphs and tele-
phones of Florida and Louisiana bear the same impor-
nt relationship to electrical communication in the Carib-
ean area that their great airports bear to transportation by
ane in the same area. Unfortunately for their drama-
zation, telegraphy and telephony lack the external evi-
ence of hustle, bustle, and glamor which characterizes the
rfields. Yet the deep strains of the ancient Saxon and
erian cultures meet and react in the electric network of
legraphs and telephones which today spans the Caribbean
just as true and significant a sense as they meet at the
rports.

Trade and commerce, news of events, personal pursuits,
atters of state—in all phases of activity wherein the peo-
es of the Americas find common ground and community of
terest—the nervous energy which darts through copper
rands or leaps from radio antennas across the water
arks and controls the more deliberate movement of men
d goods between the continents and island chains of the
estern Hemisphere. Commercial overseas telegraphy
d telephony also are linked closely to their military and
val counterparts in the attainment of strategical and
ctical objectives.

Under present conditions of emergency, cosmopolitan
izens of the United States will correctly appraise the role
communication with their southern neighbors as a
vilizing influence—at this juncture of world's history to
turned to account in promoting resistance to forces
nich would seize and suppress communication.

To cultivate friendship and amity among peoples, the lines of communication must be kept open. Each nation—any nation, *this* nation—must insist upon an opportunity to learn about all others: upon its own initiative it must inform all other countries about itself. To withdraw into isolation, to let down the iron curtain, breeds doubt, leads to suspicion and distrust, and puts an end to progress.[26] The cure for distorted information is more information, not less, that out of it all may effervesce the sparkling distillate of truth.

That is what the telephone and telegraph, radio, wire, and cable people are making possible over the communication gateways to the Caribbean to the end that the adult citizenry and the heads of states in this hemisphere shall set for all the world a good example of how to live together in peace.

REFERENCES

1. Submarine Telegraphs (book), **Charles Bright.** D. Van Nostrand Company, Inc., New York, N. Y., 1898, pages 116–118.

2. U. S. Foreign Policy: Shield of the Republic (book), **Walter Lippmann.** Little, Brown and Company, New York, N. Y., 1943, chapter 7, section 3.

3. Submarine Telegraphy in the Post-War Decade, **I. S. Coggeshall.** AIEE *Transactions*, volume 49, Part II, April 1930, pages 476–85.

4. Direct Printing over Long Non-Loaded Submarine Telegraph Cables, **M. W. Woodward, A. F. Connery.** *Electrical Engineering*, volume 51, February 1932, page 132.

5. Printing Telegraphs on Non-Loaded Ocean Cables, **H. Angel.** AIEE *Transactions*, volume 46, 1927, pages 884–96.

6. Automatic Printing Equipment for Long Loaded Submarine Telegraph Cables, **A. A. Clokey.** *Bell System Technical Journal* (New York, N. Y.), volume 6, 1927, pages 402–24.

7. Commercial Single Sideband Radiotelephone Systems, **F. A. Polkinghorn.** *Communications* (New York, N. Y.), November 1948, page 24.

8. Reins of War, **G. P. Oslin.** *Telegraph and Telephone Age* (New York, N. Y.), February-March 1946, pages 8, 14.

9. Automatic Trunk Selection in Reperforator Switching, **W. B. Blanton.** AIEE *Transactions*, volume 70, 1951 (*Proceedings T1-78*).

10. A Nationwide F-M Telegraph Network, **F. B. Bramhall, L. A. Smith.** AIEE *Transactions*, volume 70, 1951 (*Proceedings T1-62*).

11. Federal Communications Commission, 16th Annual Report. Superintendent of Documents, Washington, D. C., page 59.

12. A Century of Progress in Telecommunications, **Francis Colt de Wolf.** *American Foreign Service Journal* (Washington, D. C.), volume 21, number 5, 1944, pages 233–35.

13. Carrier Frequency-Shift Telegraphy, **R. Ruddlesden, E. Forster, Z. Jelonek.** *Journal*, Institution of Electrical Engineers (London, England), volume 94, part III-A, 1947, page 379.

14. Command Circuits, **Eldon Nichols.** *Bell Telephone Magazine* (New York, N. Y.), volume 25, 1946, pages 101–15.

15. Multi-Channel Two-Tone Radio Telegraphy, **L. C. Roberts.** *Bell Laboratories Record* (New York, N. Y.), volume 24, 1946, pages 461–65.

16. The Application of Western Union Multiplex to Navy Radio, **Ray Hoover.** *Western Union Technical Review* (New York, N. Y.), volume 2, 1948, pages 29–35.

17. Equatorial Radio Girdle. *Wireless World* (London, England), volume 50, 1944, pages 140–41.

18. Some Developments in Commercial Point-to-Point Radiotelegraphy, **J. A. Smale.** *Journal*, Institution of Electrical Engineers (London, England), volume 94, part III-A, 1947, page 345.

19. Key West-Havana Submarine Telephone Cable System, **W. H. Martin, G. A. Anderegg, B. W. Kendall.** AIEE *Transactions*, volume 41, 1922, pages 1–19.

20. Loaded Submarine Telegraph Cable, **O. E. Buckley.** AIEE *Transactions*, volume 44, 1925, pages 882–890. *Bell System Technical Journal* (New York, N. Y.), volume 4, 1925, pages 355–74.

21. New Key West-Havana Carrier Telephone Cable, **H. A. Affel, W. S. Gorton, R W. Chesnut.** *Bell System Technical Journal* (New York, N. Y.), volume 11, 1932, pages 197–212.

22. Two-Channel Submarine Carrier Telegraph System, **C. H. Cramer, E. L. Newell.** *Electrical Engineering*, volume 69, April 1950, pages 338–42.

23. Submerged Repeater for Ocean Cable, **C. H. Cramer.** *Electrical Engineering*, volume 70, July 1951, pages 566–70.

24. A Submarine Telephone Cable with Submerged Repeaters, **J. J. Gilbert.** *Electrical Engineering*, volume 70, March 1951, pages 248–53.

25. The Future of Transoceanic Telephony, **O. E. Buckley.** *Bell System Technical Journal* (New York, N. Y.), volume 21, 1942, pages 1–19.

26. A Free and Responsible Press, **Commission on Freedom of the Press.** University of Chicago Press (Chicago, Ill.), 1947

The Use of Feedback Systems for the Control of Anesthesia

R. G. BICKFORD

Electronic control steps into the operating room to aid the surgeon. Electrical activity of the patient's brain, an index of his depth of anesthesia, is used to actuate a feedback network which controls the dosage of anesthetic administered to the patient.

ANESTHESIOLOGY IS essentially an art of regulation. In the face of continually changing circumstances the anesthetist has to adjust the concentration of his anesthetic agent so that certain systems of the body are held in a state of functional inactivity, while others essential to continued existence are not unduly depressed. While in the past advances in anesthesiology have been largely concerned with the introduction of new anesthetizing agents, recently interest has been focused on methods of improving the dosage regulation of agents that have long been in clinical use. Therefore, it is not altogether surprising that this should be the first field in medicine to be invaded by concepts and devices used in the regulating systems of engineering and industry.

If the anesthetist-patient system is viewed from this standpoint it will be seen that we have an example of a feedback system with a human linkage. In this system the anesthetist receives a continuous flow of information from his sense organs (eyes, ears, and hands) which in the light of previous experience he utilizes to form a judgment of the patient's depth of anesthesia. He compares this estimate with a standard depth of anesthesia which the surgeon requires for the particular stage of the operation and then takes appropriate action to increase or decrease the anesthetic concentration. This system will be seen to be an error-actuated type of servomechanism with continuous feedback of information from patient to anesthetist. It is illustrated in Figure 1.

This is an important concept, for it leads directly to an understanding of some of the defects that may develop in such a system. These are actually of two kinds: (1) a failure to evaluate satisfactorily the information received from the patient with a consequently erroneous estimate of anesthetic depth, and (2) a lag in the system with slowness in error correction and a consequent tendency for the anesthetic depth to oscillate between wide limits. Both these defects are seen in clinical anesthesia. While the first is characteristic of the inexperienced anesthetist, the "hunting" defect appears to be present to an undesirable extent in most manually controlled anesthetic administrations.

With a view to improving anesthetic regulation a search has been made for a more reliable index of anesthetic depth than is provided by the evaluation of clinical signs. Experiments on animals[1] suggested that the electrical activity of the brain might prove satisfactory for this purpose. This activity consists of low-frequency (2–30 cycles) electric waves whose potential ranges from 100 to 500 microvolts. These electric waves (called electroencephalograms) are conducted to the surface of the head and can be recorded from metallic contacts on the scalp

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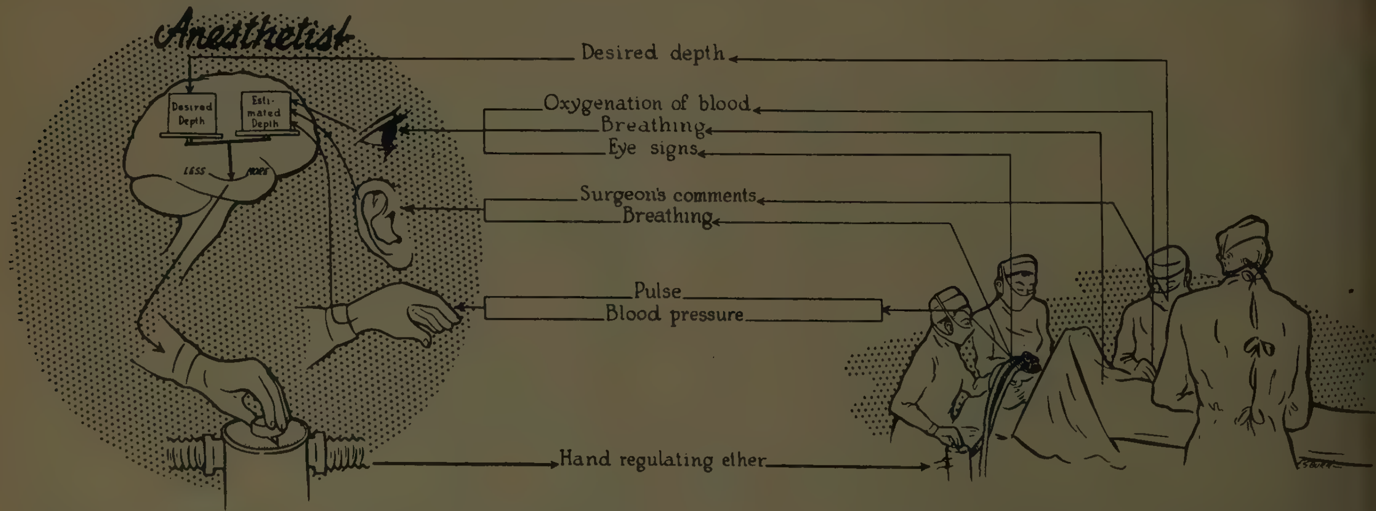

Figure 1. Diagram of the anesthetist as a human linkage in a feedback system. This is essentially an error-actuated system

r suitable amplification. When an anesthetic is given n animal the initial effect of the drug is to increase electric output of the brain twofold or threefold. As concentration of the drug rises and the stage of light sthesia is passed, a reverse effect becomes evident, and electrical output is gradually reduced until in deep sthesia all electrical activity may disappear from the in. This is illustrated in Figure 2. Similar effects are n in human beings.

Vith these patterns in mind an attempt was made to nitor depth of anesthesia both in the animal and in n exclusively from their electroencephalographic tracing l without reference to clinical data. It was soon proved t the electrical activity of the brain did provide a able index of depth of anesthesia[2] and might sometimes e an indication of approaching danger before this could detected by the usual clinical signs.

The fact that after the stage of light anesthesia has been ched the electrical activity of the brain decreases pro- ssively as anesthesia deepens suggested the possibility using the integrated potential output to operate directly ump system that would supply anesthetic to the subject. e integrator circuit used for this purpose is shown in ure 3, and Figure 4 is a diagram of the complete servo- p. This system was tested in the animal and it was nd to maintain an even depth of anesthesia over periods to two or three days. The ab- ce of hunting indicates that the esthetic agent (ether or barbi- ate) acts rapidly on the brain. periments have shown that an ect on the potential output of e brain can be seen within a ond or two of the arrival of the ug in the vicinity of the nerve ls. The small lag in the system at exists (15 to 20 seconds) is erefore accounted for mainly by e transit time of the anesthetic m the point of injection, or in- lation, to the brain. The system s also seen to make satisfactory mpensations for external disturb- ces such, for instance, as the oc- rrence of a leak in the injection sys- n. Under these circumstances a w equilibrium is reached at a ghtly lighter level of anesthesia nd greater electrical output). ne compensation is not as com- ete as would be the case in an ror-actuated system.

While the foregoing system op- ated in a very satisfactory man- r in the laboratory, its applica- n to the human subject in the erating room raised a number of esh problems. The most serious of ese was the difficulty caused by ectric interference. This can be

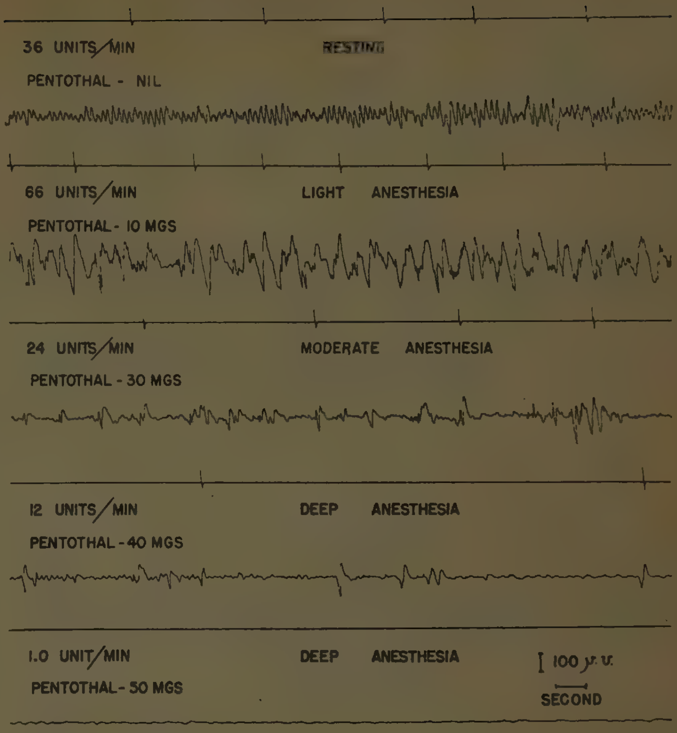

Figure 2. Changes in a rabbit brain wave pattern with deepening pentothal anesthesia. Integrator discharges are shown above the waveforms

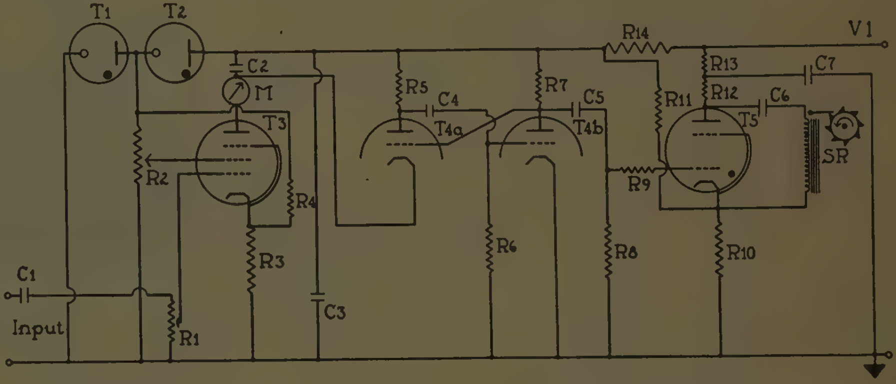

Figure 3. Integrator circuit with power-operated stepping relay. The relay shaft is geared to the plunger of a syringe

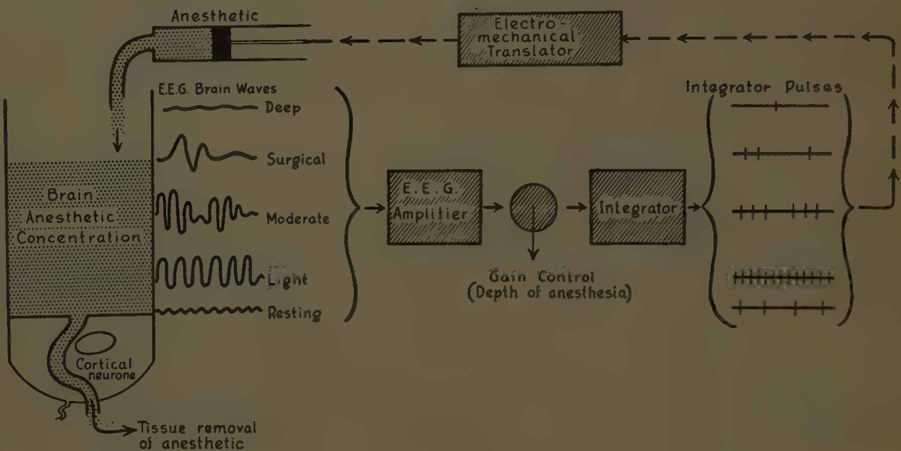
Anesthetic
Electro-mechanical Translator
E.E.G. Brain Waves
Deep
Surgical
Moderate
Light
Resting
Brain Anesthetic Concentration
Cortical neurone
Tissue removal of anesthetic
E.E.G. Amplifier
Gain Control (Depth of anesthesia)
Integrator
Integrator Pulses

Figure 4. Schematic representation of the servoloop

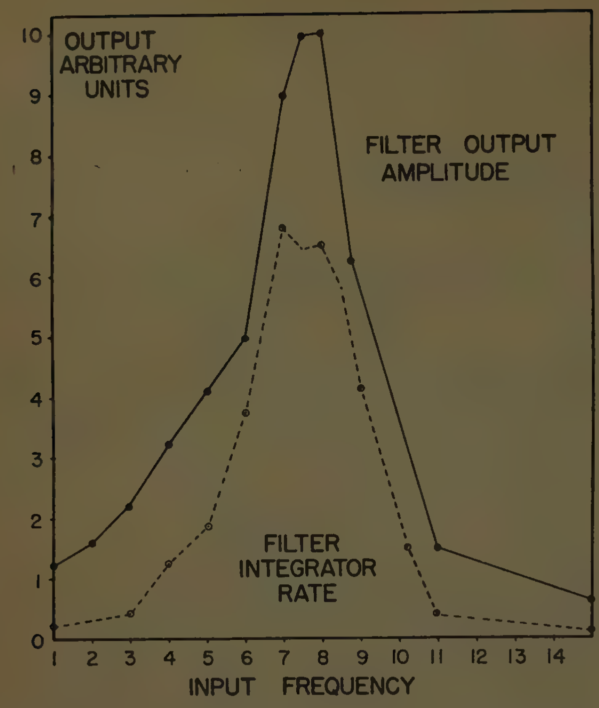

Figure 5. Frequency response of filter and filter integrator

caused by movement of static charges in relation to the head, or 60-cycle radiation from equipment operated from power mains, or high-frequency radiation from diathermy machines. The difficulties were much greater in the case of barbiturate anesthesia because the electrical output of the brain is several times less than occurs in ether anesthesia.

The problem is essentially one of increasing the signal-to-noise ratio, so familiar to communication engineers.

The occurrence of unwanted disturbance at the high and low ends of the frequency spectrum of brain potentials suggested that a band of frequencies might be found in the middle part of the spectrum that would give relative immunity from interference while still retaining the progressive fall in amplitude with deepening anesthesia on which automatic control is based. To investigate this possibility harmonic frequency analyses were made of the electroencephalogram in relation to increasing depths of barbiturate anesthesia. These studies showed that the band of frequencies between 6 and 10 cycles per second contained all the necessary information for anesthesia control. A frequency discriminating system achieved by means of a phase-shift network was therefore incorporated in the servoloop. The frequency response curve of the network is shown in Figure 5. This system has been found to give excellent discrimination against interference as is shown in Figure 6 where it is compared with the original wide frequency pass system. Experiences with animals have shown that the narrow pass system gives a control ratio (ratio of injection rate in light anesthesia to rate in deepest level) of the order of 60, thus insuring good regulation. It was proved equally satisfactory in its application to human anesthesia.

The question will now be asked whether the information contained in the electrical brain signal will be sufficient to permit satisfactory regulation in the face of such disturbances as, for instance, the onset of surgical shock associated with bleeding or that of poor oxygenation associated with obstruction of the breathing system. Fortunately under these circumstances the brain signal is reduced in much the same way as it would be with deepening anesthesia so that the proper action would be taken to reduce the dosage of anesthetic agent. However, since this re-

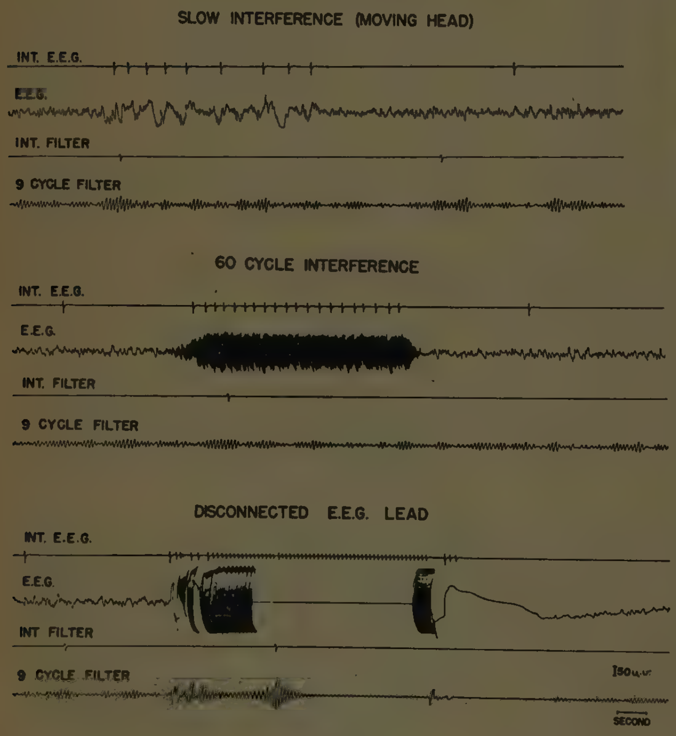

Figure 6. Comparison of wide and narrow filter with respect to discrimination against interference. INT. E.E.G.—direct integration of electroencephalogram. INT. FILTER—integration of filter output

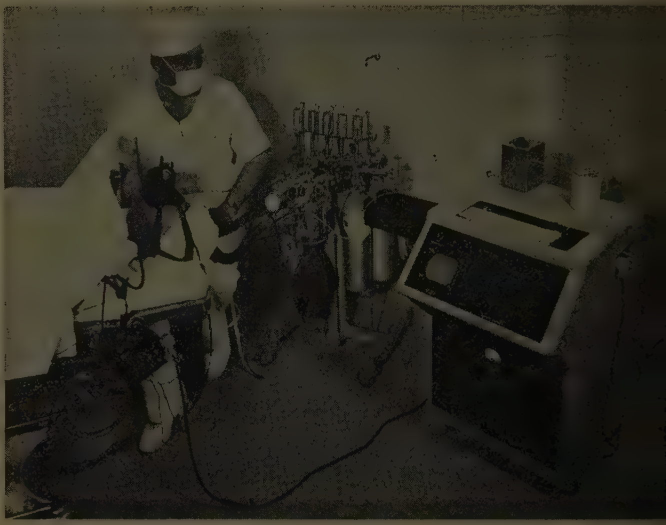

Figure 7. The servo-anesthetizer in use for the administration of ether anesthesia. Ether reservoir and pump are seen on top of the machine. A fine plastic tube conveys ether from pump to the vaporizer. A cathode-ray tube is provided for monitoring and a penmotor makes a permanent recording of brain waves

onse might in some instances be unduly delayed it has een thought advisable to include a breathing indicator the system and to adjust it so that if the volume falls low a certain critical value a warning is given and the rvo-administration is stopped. The possibilities of in- uding a combined anoxia and blood pressure indicator e being investigated. The complete servo-system in use r automatic administration of ether is shown in Figure 7.

To what extent this relatively simple servomechanism ill replace the human linkage type in practical anesthesia mains to be seen. Its main application is likely to be the ntrol of anesthesia in the presence of the relaxant drug, curare, the action of which invalidates most of the anesthetist's clinical signs. The servo-anesthetizer will certainly find important application in the research field, where the accurate control of level of anesthesia in animals over long periods is often crucial to the success of the experiment.

REFERENCES

1. Automatic Electroencephalographic Control of General Anesthesia, **R. G. Bickford.** *EEG Clinic of Neurophysiology*, International Federation of E.E.G. Societies, Montreal, Quebec, Canada, volume 1, February 1950, pages 93–96.

2. The Classification and Significance of Electroencephalographic Patterns Produced by Nitrous-Oxide on Ether Anesthesia During Surgical Operations, **R. F. Courtin, R. G. Bickford, Albert Faulconer, Jr.** *Proceedings of the Staff Meetings*, Mayo Clinic (Rochester, Minn.), volume 25, April 12, 1950, pages 197–206.

Development of a Pumpless Ignitron

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This large metal-tank ignitron requires no vacuum pump. Thus it is more flexible for many installations and is simpler to construct. Some of the problems of making the rectifier vacuum-tight and methods for detecting leaks are discussed.

WHEN LARGE METAL TANK rectifiers were first built, it was found necessary to provide them with vacuum pumps operating continuously because e techniques for making vacuum-tight joints and seals d for adequately degassing internal parts were not avail- le. Many such pumped ctifiers are in service day. However, efforts to iminate the pumps have rsisted. In the United ates, sealed ignitron tubes r rectifiers in the smaller zes were developed over ten ears ago. These tubes fea- e glass to metal seals and ainless-steel envelopes. In Europe, multianode air- oled rectifiers of small or medium size have been built r a number of years. They feature either soldered etal to porcelain or fused metal to enamel seals and w-carbon steel envelopes.

A pumpless ignitron rectifier has now been developed r use in the higher ratings. It incorporates many of e features of the large pumped ignitrons which have oved so successful. The rectifier tank is constructed that it may be reconditioned readily at either the factory the installation. It is expected to have a minimum rvice life of five years before reconditioning is necessary d an ultimate life of 20 years or more.

DESIGN PROBLEMS

N ORDER THAT a rectifier operate for long periods of time without vacuum pumps, two requirements must met: air leakage through the walls, welds, and seals the vacuum envelope must be held to a low value; and the internal parts must be degassed so that a good vacuum is maintained during operation. These requirements impose a number of design problems.

Special measures are necessary to assure the required vacuum tightness. It is not possible to construct a vacuum chamber with no leakage, for if sufficiently sensitive instruments are available it will be found there is always some leakage, although it can be made very small. To minimize the leakage in welds the tank construction has been arranged to reduce the length of weld to a practical minimum. All openings are made with spun or pressed flanges instead of fabricated flanges. If possible, welds are eliminated by making two parts out of one piece. Where possible, double welds are used. Special precautions are taken to make welds under most favorable conditions by positioning and completing welds in a single pass. The ignitor seal is demountable and utilizes a gasketed joint. To reduce the leakage through this joint to an acceptable value a special gasketed joint was developed. To facilitate reconditioning, the tank is equipped with a vacuum valve which is sealed off after degassing. It was found that a valve is not sufficiently tight for long life. To prevent the leakage through the vacuum valve, an arrangement was developed for placing a cap over the valve so as to form a

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Essential text of paper 51-212 "Development of a Pumpless Ignitron," recommended by the AIEE Committee on Electronic Power Converters and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Toronto, Ontario, Canada. Scheduled for publication in AIEE Transactions, volume 70, 1951.

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chamber on the atmospheric side of the valve which in turn could be evacuated and sealed off by means of a glass tubulation.

When water cooling is used on pumpless tanks careful consideration must be given to the prevention of corrosion, as the nascent hydrogen liberated by the corrosive action readily penetrates ordinary steel and enters the vacuum chamber.[1] Several arrangements may be used for avoiding corrosion. If the tank is built of low carbon steel, the corrosive action may be inhibited by treating the water with sodium chromate.[2] A tank of low carbon steel may be cooled with untreated water if it is provided with copper cooling coils soldered in place. Another possibility is to build the tank of stainless steel.

Except for the modifications necessitated by the design requirements mentioned, the construction of the pumpless ignitron is similar to that of the pumped rectifier. A sectional view of a 16-inch pumpless ignitron is shown in Figure 1. The starter assembly is bolted in place so that it may be readily removed for cleaning of the mercury pool, replacement of the ignitor, and inspection during normal reconditioning operations. The cover assembly is welded into place and arranged so the weld may be ground off if more extensive maintenance is required during reconditioning. A wide cover flange is provided so the cover may be removed about one-half dozen times and rewelded. Anode, grid, and ignitor seals are of mycalex molded construction. The rectifier tank is of deep-drawn low-carbon steel and is made by a series of drawing operations. The tank is evacuated through a seal-off valve located on the cover. The valve arrangement is shown on Figure 2. Other features are similar to those employed on standard pumped ignitrons.

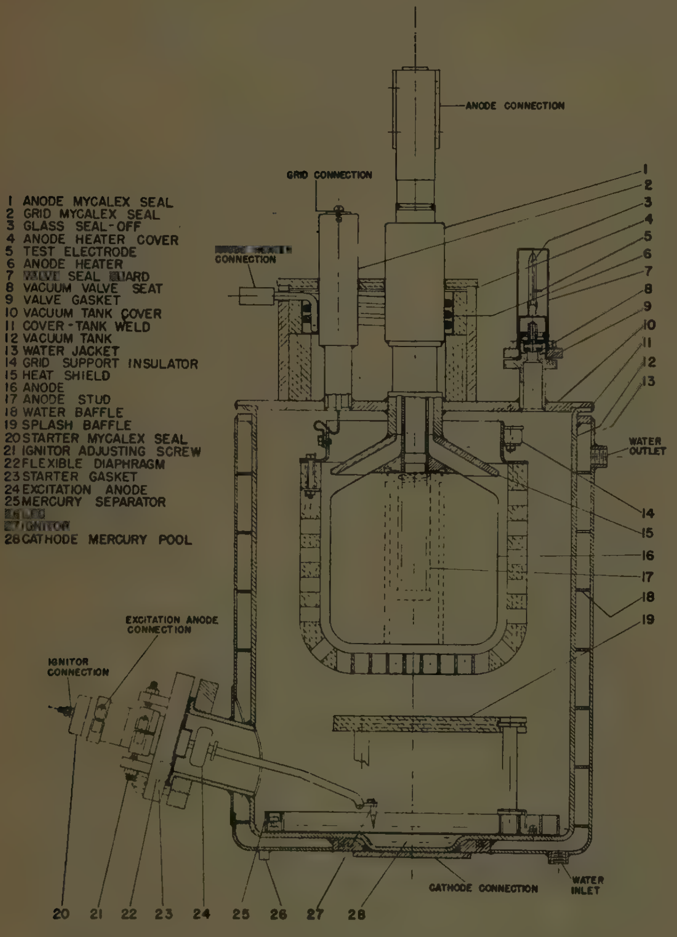


Figure 1. Sectional diagram of the pumpless ignitron

VACUUM TESTING AND DEGASSING

THE DEVELOPMENT of the pumpless rectifier has been delayed to this late date in large measure by the lack of practical means for locating small vacuum leaks. However, the last ten years have seen the development of the halogen-type leak detector[3] and the helium leak detector.[4] These two instruments eliminate the need for the slow, tedious, and costly air-pressure soap-bubble test and provide means for locating very small leaks rapidly and easily.

The halogen-type leak detector is especially useful in making factory tests during manufacture in checking vacuum welds, seals, gaskets, and metal parts. Tests are made by filling the chamber to be tested with compressed air containing a low concentration of halogen vapor, such as ethylene dichloride or carbon tetrachloride. A suction tube which draws air through the sensitive elements of the halogen detector then is passed over the suspected surfaces of the vacuum vessel and indication is obtained on the halogen detector whenever leakage of the halogen vapor mixture occurs.

Final vacuum tests are made by means of the helium leak detector, which is an adaptation of the mass spectrometer. For these tests, the rectifier tank is evacuated and the exhaust system is connected so that samples of the gas pumped out of the rectifier may be passed through the mass spectrometer. The rectifier tank or any part of it is then enclosed in a bag which is filled with helium. If there is any helium leakage through the rectifier tank, an indication is obtained on the leak detector.

After the rectifier has been placed in service, some method for checking the vacuum without breaking the vacuum seal is desired. From tests it has been found that a rough measure of the vacuum may be obtained by measuring the arc drop with a low value of direct current passing through the tank. Tests have shown that as the foreign gas pressure increases in a range from zero to 250 microns, the arc drop increases likewise at nearly a linear function of pressure. Figure 3 shows the circuit used for making the arc-drop measurements and the variation in arc drop with foreign gas pressure for a particular rectifier tank.

After a rectifier has been made vacuum-tight so that no gases can leak in and has been evacuated, that is, all mobile gases pumped out, it must be degassed before it is operable. The degassing process consists in raising the temperature of the internal parts of the rectifier and removing the gases that are liberated.

Pumpless rectifier tanks must be so thoroughly degassed that they will not become gassy during operation. Experiments have shown that when a rectifier is degassed for a long time with the internal parts at a constant temperature, the gas liberation will diminish and apparently cease. If the temperature then is raised, for example, by increasing the degassing current, more gases will be released.[5] Apparently, all the absorbed gases are never removed from the internal parts. What then determines the amount of degassing required?

Two criteria for adequacy of degassing have been established. The first of these requires that the degassing process be carried to levels of temperature equalling those expected in service. This means that the internal parts of the rectifier must be subjected to temperatures approximating those experienced in service for a sufficiently long time to liberate and remove the absorbed gases so that these gases will not be liberated when operating in service, causing a gassy tube.

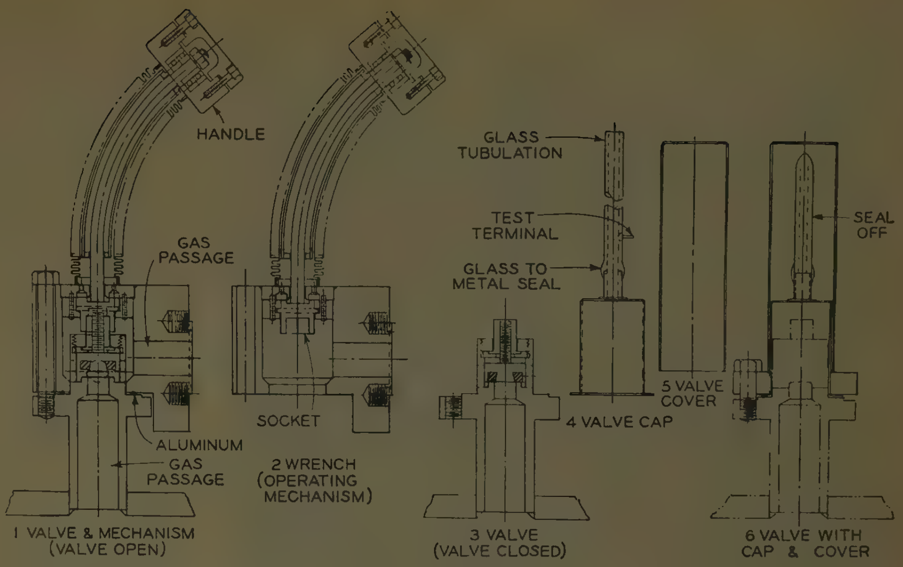


Figure 2. Seal-off valve through which the tank is evacuated

If it were absolutely necessary that all parts of the rectifiers be carried above the temperature levels experienced in service, so that no gases would be liberated during operation, the construction of a pumpless rectifier would be difficult if not altogether impractical. It would be necessary to employ extreme measures to make sure that all parts have been adequately degassed, not only for the usual temperatures encountered in normal operation but also for the unusual temperatures that might be rarely experienced during faults, overloads, or other abnormal conditions. Extremely long degassing periods might be required to take care of those parts which degass very slowly and continue to liberate gases for a long time. Also, there would be no provision for steady deterioration in condition incurred because of the inevitable small leakage which takes place. These difficulties are all removed because of an absorption action exhibited by the rectifier.

Tests have shown that if an arc is established in a rectifier tank which has been degassed but contains a small quantity of foreign gas in mobile state, the gas will disappear.[6] The manner of its disappearance depends upon the nature and amount of the gas and the condition and character of the internal parts of the rectifier. Those gases which are chemically active such as oxygen, nitrogen, and so forth, disappear quite rapidly; the inert gases, such as argon, neon, and so forth, more slowly. The action involves absorption of the gases by the tank walls and electrodes and depends upon the condition of these parts resulting from the degassing treatment.

The second requirement for adequate degassing is that the degassing process be carried to temperatures sufficient to provide ability to absorb any gases which may be liberated by rectifier parts during operation or which may seep in from the inevitable small leakage.

Various processes may be utilized for degassing. For example, the degassing may be carried out directly by operating the rectifier with a degassing current exceeding the maximum current expected in service. Degassing also may be accomplished by heating the major parts of the rectifier by radiation or induction. Or, again, the various parts, such as anodes, grids, and so forth, may be separately treated before assembly in the rectifier. The choice of degassing procedure becomes then an economic one of finding the simplest and lowest cost methods of providing adequate gas removal.

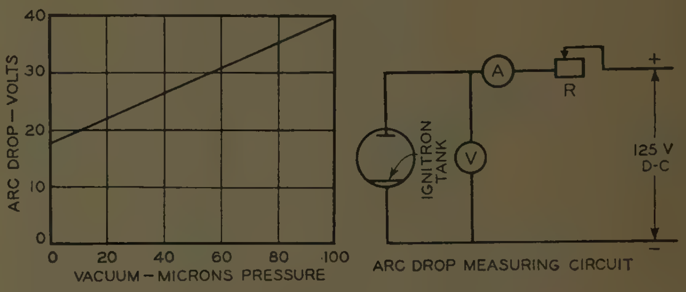


Figure 3. Circuit used for making arc-drop measurements and a plot of arc drop versus vacuum in the ignitron

In an effort to determine the most effective and economical degassing procedure, extensive tests have been made in which both the quality and quantity of gas removed during degassing were measured, with the conditions for liberation determined in terms of temperature, current, and time. The kinds of gases liberated during the degassing process were determined by means of another new instrument, the mass spectrometer. Samples of the gases liberated during degassing were passed through the mass spectrometer at regular intervals during the degassing period. Measurements of gas flow were obtained from the pressure reading during degassing and also by means of a special manometer.

Two general degassing procedures were used during developmental tests. In the first, which was conducted without mercury in the rectifier, the tank walls were heated to various temperatures up to 500 degrees centigrade. Following this wall degassing, the mercury was admitted to the rectifier without breaking vacuum and

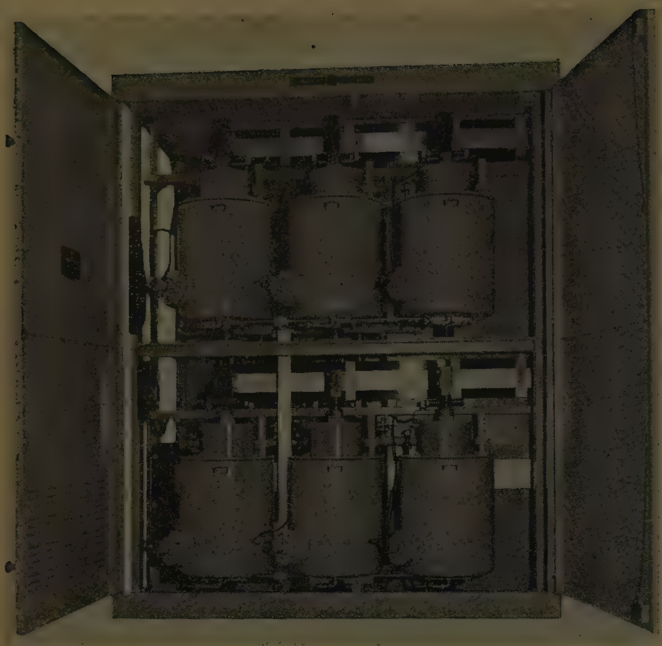


Figure 4. A typical installation of pumpless ignitrons

the rectifier was then given a current degassing in the normal manner used on pumped rectifiers and carried to current levels exceeding those expected in service.

Laboratory tests have shown that zirconium may be used as an effective getter in the presence of mercury vapor. This may prove to be the most economical method for providing the desired absorbing ability in a rectifier. However, tests which have been made so far indicate that the need for a getter is not sufficient to justify the complications introduced by the use of zirconium.

The first pumpless ignitron was shipped from the factory in August 1948 and was placed in service about two months later in a steel wire mill at the Wickwire Spencer Division, Buffalo Plant, of the Colorado Fuel and Iron Company. The unit has operated since that time without arc back at a load factor of approximately 80 per cent. It consists of six pumpless tanks rated 1,000 kw at 250 volts and 4,000 amperes. These pumpless ignitron tanks were sealed off at the factory prior to shipment and have now operated over $2^{1}/_{4}$ years without degassing or pump down. Periodic arc-drop measurements give no indication of increasing gas pressure.

On the basis of the very favorable factory and field tests additional installations of pumpless ignitrons have been undertaken. Figure 4 shows a photograph of a 1,000-kw 250-volt pumpless ignitron equipment recently supplied to the Baltimore and Ohio Railroad Company. This equipment illustrates some of the advantages obtained by use of the pumpless ignitron tank. The absence of a vacuum pump makes possible a much more compact installation.

CONCLUSIONS

THE FINAL MEASURE of the pumpless tank is, of course, an economic one. To successfully replace the pumped ignitron, it must do the same job at an equal or lower over-all cost. The cost incurred by the greater care to obtain suitable vacuum tightness and the additional degassing required for pumpless operation must be balanced by savings resulting from the elimination of vacuum pumps and manifold connections and the simplification of the rectifier assembly. Likewise the maintenance costs incurred in reconditioning must be of the same order as those which are met in maintenance of vacuum pumps and systems.

The pumpless rectifier presents an improvement which has long been desired as it makes possible a simpler rectifier construction with greater flexibility of arrangement. It is expected that the present pumped rectifier will in time be supplanted by units of the pumpless types.

REFERENCES

1. Diffusion of Hydrogen From Water Through Steel, **Francis J. Norton.** *Journal of Applied Physics* (New York, N. Y.), volume 11, number 4, April 1940, page 262.

2. Water Cooled Steel Tank Rectifier Corrosion Problem, **E. J. Remscheid.** *AIEE Transactions*, volume 60, April 1941, page 173.

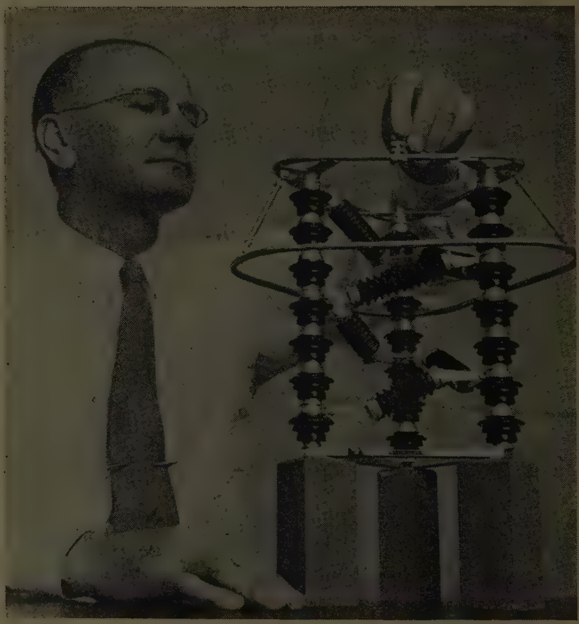
3. Positive Ion Emission, A Neglected Phenomena, **W. C. White.** *Proceedings of the Institute of Radio Engineers* (New York, N. Y.), August 1950.

4. High Vacuum Leak Testing With the Mass Spectrometer, **W. G. Worcester, E. G. Doughty.** AIEE *Transactions*, volume 65, 1946, pages 946–55.

5. The Degassing of Metals, **F. J. Norton, A. L. Marshall.** *Transactions*, American Institute of Mining and Metallurgical Engineers (New York, N. Y.), volume 104, 1933, Institute of Metals Division, page 136.

6. The Absorption of Gases by the Steel Walls of Vacuum Discharge Apparatus and Its Bearing on the Life of Pumpless Mutators, **W. Deck.** *Brown Boveri Review* (London, England), volume 29, 1942, page 202.

Spiral Lightning Arrester



Shown here with a model of a new high-voltage lightning arrester for use on 230-kv lines is A. M. Opsahl of the Westinghouse Electric Corporation, the designer. Only half as tall (10 feet) as former high-voltage units that required large structural steel supports, the new type *SV* station-type device features a zigzag arrangement of the lightning-arrester units that eliminates the need for such supports. Lightning surges are carried groundward through the spiral arrangement between the three vertical columns

Transient Response of Small 2-Phase Motors

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ASSOCIATE AIEE

SMALL 2-phase induction motors are used frequently in the construction of servomechanisms in instruments and computors. An analysis of the transient performance of such motors is desirable as an aid in servomechanism design.

This article presents a general solution for the transient response of a 2-phase induction motor, based on assumptions which are close approximations for most control motors.

First, it is assumed that the motors have identical windings or can be made equivalent to such motors by the use of transformers. Second, it is assumed that the electrical time delays in the motor windings are so small compared to the significant portion of the motor transient response that their effects can be neglected without appreciable error. Third, the steady-state speed-torque curves for balanced applied voltages can be approximated by straight lines. Fourth, the load torque consists of coulomb and viscous friction only.

Using these assumptions, the properties of 2-phase motors, and the method of symmetrical components, it is possible to write an expression relating applied field voltages, motor-shaft angular velocity, and time. This expression is a first-order linear differential equation with variable coefficients. A general solution is in the form

$$\omega=\epsilon^{-\int\frac{K[V_A{}^2(t)+V_B{}^2]+2b\omega_0}{2\omega_0J}dt}\int\frac{KV_A(t)V_B-a}{J}\epsilon^{\int\frac{K[V_A{}^3(t)+V_B{}^2]+2b\omega_0}{2\omega_0J}dt}dt$$

where ω is the instantaneous shaft velocity, K is the torque constant of the motor in stalled torque per field volts squared, $V_A(t)$ is the *amplitude* of the alternating voltage applied to the control field, V_B is the constant amplitude of reference field alternating voltage, b is the coefficient of viscous friction, a is the coefficient of coulomb friction, ω_0 is synchronous shaft velocity in radians per second, and J is the effective rotary inertia of the rotor and load combined.

In the case where the voltage applied to the reference field is of constant amplitude, and the voltage applied to the control field has a step change of amplitude, the solution is of the form

$$\omega=\omega_{ss}\left(1-\epsilon^{-\frac{t}{T}}\right)$$

where

$$\omega_{ss}=\text{steady-state shaft velocity}=\frac{2\omega_0(KV_AV_B-a)}{K(V_A{}^2+V_B{}^2)+2b\omega_0}$$

$$T=\text{motor time constant}=\frac{2\omega_0J}{K(V_A{}^2+V_B{}^2)+2b\omega_0}$$

Thus for any given amplitude of reference-field voltage and step amplitude change of control field voltage, the response is exponential. The time constant T of the response is not a true motor parameter, but varies with variations of the applied voltage amplitude, becoming smaller as the applied voltages are increased.

A solution for the steady-state response of the motor for a constant-amplitude reference voltage and a sinusoidally-modulated control-field-voltage amplitude is not obtained readily except for the case of very small amplitudes of control-field-voltage oscillation. For this case the motor behaves like a single-time-constant linear system. The motor cannot be considered a linear device for large amplitudes of control-field-voltage oscillation. Figure 1 shows the motor response to small input oscillations.

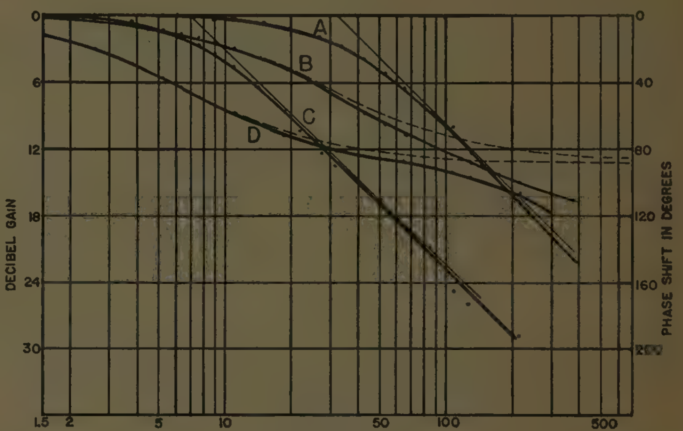

Figure 1. Frequency response for a Diehl type FP-25 motor with 20 volts amplitude on the reference field and a sinusoidally varying voltage amplitude on the control field. Curves A and B are gain and phase curves for 0.01 ounce-inch squared rotor inertia; C and D for 0.05 ounce-inch squared rotor inertia. Dashed lines show theoretical phase shift

The conclusions drawn are that the 2-phase motor has a damping factor which is a function of the applied field-voltage amplitude, and that the motor response to changes of control-field-voltage amplitude is slower for low values of applied control-field-voltage amplitude than for high values. The possibility of controlling the damping factor of the motor by controlling the amplitudes of the voltages applied to the motor fields is indicated.

A further conclusion is that while the motor frequency response based on small input oscillation may be used for control-system stability calculations, the frequency response approach may not be valid when considering the effects of large inputs.

Digest of paper 51-163, "Transient Response of Small 2-Phase Induction Motors," recommended by the AIEE Committee on Feedback Control Systems and approved by the AIEE Technical Program Committee for presentation at the AIEE Great Lakes District Meeting, Madison, Wis., May 17–19, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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Three-Phase Delta Submarine Cable Characteristics

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THE RECENT INSTALLATION by the British Columbia Electric Company of a 3-phase delta-connected submarine power cable circuit, in which two of the conductors are single-core cables and the third conductor is the ground path, appears to be an innovation in submarine cable practice. The circuit is laid in the Pacific Ocean from the British Columbia mainland to an island about three miles off shore. The depth of the sea water in the channel is about 800 feet. When the project first was conceived, it was taken more or less for granted that armored 3-conductor cable would be installed, since this type of cable previously had been the conventional choice for submarine power cable work. However, upon detailed analysis it was found that single-conductor cable would have outstanding advantages. These advantages were evident in all three main aspects of the project; namely, the dollar economy of the complete installation, the physical handling of the cable, and the electrical operation of the circuit. The studies made lead to the conclusion that in many submarine installations, the traditional use of 3-conductor cable might well be abandoned in favor of single-conductor cable.

Considering first the matter of dollar economy, the cost of a single-conductor cable is only slightly more than one-third the cost of a 3-conductor cable. Where the purpose of the circuit is to serve a small load having potentialities for growth, the initial installation can be a single-conductor cable. This would provide a single-phase circuit, using the armor as a grounded return conductor. Where the load to be served is an isolated community on an offshore island, a typical case, single-phase service would be adequate for most, if not all, of the potential load. At a later stage when 3-phase service is required, a second single-conductor cable can be added to form a 3-phase grounded delta circuit. Transformations may be required to isolate the grounded delta submarine section from the supply system at the source end and the distribution system at the utilization end. If reliability of the service becomes important, a third single-conductor cable can be added to the circuit. This does not provide any increased carrying capacity but gives the installation the equivalent of a spare circuit.

It may be observed that in the case of a 3-conductor cable a failure generally will put the entire circuit out of commission. With single-conductor cable a failure in one cable of a 3-cable circuit still permits 3-phase service to be supplied, by using grounded-delta operation. A failure in one cable of a 2-cable circuit still permits single-phase service to be supplied. Thus, the reliability of such single-conductor cable circuits is much greater than for a 3-conductor cable.

At a still later stage of load growth, the addition of a fourth single-conductor cable will double the circuit capacity by providing two grounded delta circuits. At each stage the investment in cable can be substantially less than for a 3-conductor cable that will handle the same amount of load.

In the matter of physical handling, all the advantages are again on the side of a single-conductor cable. The ideal situation for cheap and expeditious laying of submarine cable is to have the full length contained on a single reel. This eliminates having to lay the cable out in figure-8 formation on flat cars or barge or cable ship at the shipping and destination points and eliminates joints in the undersea cable. Inasmuch as single-conductor cable is substantially smaller and lighter than 3-conductor cable, the length that can be contained on a single reel is two to three times as great. This permits much longer routes to be laid, without joints, by the quickest and least expensive method. In the case of the British Columbia installation, a length of about one mile of 3-conductor cable was the most that could be obtained on a single reel. The route length was slightly over three miles. Single-conductor cables were obtained in reel lengths of 16,300 feet without undue difficulty. The armoring was composed of aluminum alloy wires, which lightened the weight. Each full reel weighed 26 tons, but this presented no particular difficulty either in shipping or handling during the installation.

The electrical operation of the grounded delta submarine circuit, consisting of two single-conductor cables with aluminum-alloy armor, has been analyzed. It is concluded that such a circuit has several points of superiority over the conventional 3-conductor cable, when the line length exceeds about one mile and the load is small and isolated. The total circuit losses, including sheath losses, are less than for the 3-conductor cable and less than for a 3-phase open wire line of the same conductor size. The average impedance of the circuit is less than that of an equivalent open-wire line. The impedance of the grounded phase is considerably lower than that of the other two phases, but this is not considered to be objectionable. The magnitude of the current flowing in the sea water and earth is insignificant, being less than 15 per cent of the load current. The greater reliability of the circuit has been pointed out already. If transformers are required to isolate the grounded-delta section of the circuit, this might be considered objectionable. However, the disadvantage appears to be minor in comparison to the over-all superiority of the circuit.

Digest of paper 51-233, "Electrical Characteristics of a Three-Phase Delta Submarine Power Cable Circuit Using Earth As One Conductor," recommended by the AIEE Committee on Insulated Conductors and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Toronto, Ontario, Canada, June 25–29, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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The Relationship of Hydroelectric Power to the Columbia River Basin Development

O. E. WALSH

While hydroelectric power generation is only one aspect of the development of a river valley, it is an essential one. General O. E. Walsh of the Corps of Engineers describes the Columbia River Basin development and the part that water power plays in this great project.

As ELECTRICAL engineers, when you think of water resource development you naturally think of hydroelectric power. This important phase of development of our water resources has been given particular emphasis since the Korean War and the ensuing emergency. But the multiple resources of the Columbia River Basin are so integrated into an economic pattern that we of the Corps of Engineers—in this river basin as in others throughout the nation—have come to view water resources as a unified whole and to study their development from the standpoint of extracting the greatest possible number of individual benefits, each in the greatest possible degree that can be economically justified. Our ultimate objective is to achieve a balanced utilization of resources in the full development of the Columbia River and tributaries.

The Columbia River rises in a mountain lake on the west slope of the Canadian Rockies, 2,650 feet above sea level. It flows northwestward through one of the trenches which mark the northern Rocky Mountain system, cuts through into an adjacent trench, and then courses southward. After entering the United States near the northeastern corner of Washington, the Columbia crosses that state in a series of big bends, then takes its final westward course in a gorge through the Cascade Mountains. The river discharges annually into the sea nearly 180,000,000 acre-feet of water—more than any other river in the nation except the Mississippi.

The Columbia's major tributary, the Snake River, drains about 110,000 square miles, or approximately half the United States portion of the Columbia River Basin. Some 1,000 miles long, its annual discharge into the Columbia is approximately 37,000,000 acre-feet. The Clark Fork and Kootenai Rivers, which drain most of western Montana and northern Idaho, join the Columbia in Canada. Other major tributaries are the Spokane, Yakima, Deschutes, Willamette, and Cowlitz Rivers.

The important place of power development in the Columbia River Basin is indicated by the fact that the Pacific Northwest states of Oregon, Washington, and Idaho, though comprising only about 8 per cent of the total area of the United States, have 37 per cent of the hydroelectric potential of the entire nation. It is hardly surprising, in view of this fact, that in an emergency like the present one, the rest of the nation is looking to the Pacific Northwest as the logical best source of hydroelectric power for new defense industries, as well as expansion of some industries already located here.

MULTIPLE-PURPOSE PLANNING

As CARRIED OUT by the Corps of Engineers, major planning is not directed toward accomplishing only one purpose at a time, whether improvement for navigation, protection of a single area from floods, or development of hydroelectric power. Single-purpose planning can best be done within the framework of a genuinely comprehensive over-all plan, with the local need in harmony with the requirements of the basin as a whole and the immediate plan consistent with long-range potential developments. Only comprehensive multiple-purpose planning, in which development of all water uses is co-ordinated, is justifiable. In this way individual uses are served at less cost than if each purpose were developed independently.

In July 1943 the Chief of Engineers, pursuant to general authority granted him by Congress in the River and Harbor Act of 1935, directed the initiation of plans for the revision of the *308* report. About two months later, in September 1943, the United States Senate passed a resolution directing the Corps of Engineers to extend and revise the report with a view to preparing a comprehensive water resources plan for full flood control, power, navigation, irrigation, and other benefits in the Columbia Basin. Through the efforts of the International Joint Commission, the full co-operation of Canada was obtained.

Known as the Columbia River and Tributaries Review Report, this revised plan was completed by the Division Engineer in October 1948. It was the result of five years of studies and it provided a basis for the optimum development of water resources of the Columbia River Basin during the next 20 or more years in the interest of flood control, power, navigation, irrigation, drainage, recreation, and other benefits. The study had the benefit of close collaboration with many state and federal agencies, including the Bonneville Power Administration, United States Fish and Wildlife Service, Soil Conservation Service, Bureau of Reclamation, and other federal agencies, and by the Pacific Northwest states.

Reviewing all major regional and local water-use

Full text of an address presented at the AIEE Pacific General Meeting, Portland, Oreg., August 20–23, 1951.

Brigadier General O. E. Walsh is Division Engineer, North Pacific Division, United States Army Corps of Engineers, Portland, Oreg.

problems, the plan provided for co-ordinated development and operation of projects already constructed, those authorized for construction, and others under consideration for possible construction in the foreseeable future. It also laid the groundwork or pattern for an extended development in the period to follow.

The general objective, then as now, was to utilize all the water resources of the river to the utmost within the scope of economic limitations embodied in the Congressional directive. Many projects were included in the over-all plan proposed by this report, but only those deemed most feasible and essential to fill existing requirements were recommended for early authorization.

Immediate authorization of a co-ordinated development program was recommended which provided for:

1. A fully developed navigable channel of varying dimensions from 30 miles above Lewiston, Idaho, to Portland and the sea. It would be canalized from Bonneville to Lewiston.
2. Flood control measures consisting of levees and multiple-purpose reservoirs adequate for control of all floods that had ever occurred on the Columbia.
3. Modification and extension of the Willamette Valley Project, providing a comprehensive subbasin plan for flood control, power, navigation, and other purposes.
4. Other subbasin plans, comprising local flood protection works and navigation improvements throughout the region.
5. The development of additional hydroelectric power in the projects with an installed generating capacity of about 6,500,000 kw, and transmission facilities to carry this power to principal load centers.
6. Construction of 13 irrigation developments as recommended by the Secretary of Interior in June 1948.
7. Adequate measures for conservation of soil and forest cover as recommended by the Soil Conservation Service of the Department of Agriculture.
8. Hydrometeorological network to furnish precipitation, stream flow, and other data for operation of multiple-purpose reservoirs, operated co-operatively by various participating agencies.
9. A lower Columbia Fisheries program developed by the United States Fish and Wildlife Service to insure preservation and enhancement of salmon runs.

The Main Control Plan of this Columbia River Review Report recommended immediate authorization of ten major projects, including seven multiple-purpose dams and reservoirs, in the interest of flood control, navigation, hydroelectric power, and other water uses. These major recommendations were:

1. Libby Dam on the Kootenai River in northwestern Montana.
2. Albeni Falls Dam on the Pend Oreille River in northwestern Idaho.
3. Priest Rapids Dam on the Columbia River in Washington.
4. Hells Canyon Dam on the middle Snake River in Idaho and Oregon.
5. John Day Dam on the Columbia River in Oregon and Washington.
6. The Dalles Dam on the Columbia River in Oregon and Washington.
7. Glacier View Dam on Flathead River in northwestern Montana (or suitable alternate).
8. Modification of Grand Coulee Dam and Hungry Horse Dam, Bureau of Reclamation projects, and adoption of specific procedures for effective operation of the two reservoirs in the interest of flood control as well as irrigation.
9. Construction of new levees and provision of flood walls and bank protection, supplementing flood control provided by storage in the recommended reservoirs, for protection of lands along the lower Columbia River.
10. Open river navigation improvements on the Snake River for 30 miles above Lewiston, Idaho, and construction of approach channels and turning basins at major port terminals on both the Columbia and Snake Rivers.

A number of projects recommended in this Review Report have since been authorized by Congress for construction and construction is already under way on one project—Albeni Falls Dam.

I hope that my foregoing remarks have provided a general picture of the regional objectives in which the hydroelectric power resource plays so important a part. These massive multiple-purpose structures are justified for several purposes but the increasing market for electric energy, particularly since power can be provided at a very low cost, is the main element of justification in all the major projects. I would like to confine my remarks now to the part that hydroelectric power plays in the over-all basin development.

FLOOD CONTROL AND POWER GENERATION

As everyone knows, the Columbia River and tributaries, with their vast drainage areas and enormous runoff, partially governed by melt of snow storage in the highlands, have a tremendous power potential which in its present stage of development is virtually untouched.

It is not so well known that storage space can be equally valuable and can be used in the dual interest of flood control and power generation without conflict. This is a unique condition. In most parts of the country these two interests are not entirely compatible with each other. This compatibility results because the uniform seasonal runoff pattern of the Columbia for the low runoff period and the seasonal high water period are so timed yearly that regulation of flow for one purpose may well improve conditions for other purposes.

Hence, the destructive spring and early summer snowmelt floods of the Columbia Basin area east of the Cascade Range are controlled by impounding excess runoff in storage reservoirs for release during the late summer months for irrigation, and through the fall and winter months for power generation.

Diversity of stream flow and power loads in this vast region is another factor of importance. With respect to runoff, this diversity is extremely important in making full use of the water resources for power from our streams west of the Cascades. The comprehensive plan for the

Willamette Basin incorporates this diversity factor to the utmost. Likewise, power plants on the Puget Sound slopes integrate with the Columbia River power very effectively.

This diversity in flow results because the annual discharge pattern for tributaries of the Columbia River east of the Cascades follows in general that of the Columbia River itself, with low flows from September through March and high flows from April through August. On the other hand, the discharge pattern for streams west of the Cascades follows the precipitation pattern with minimum flow between June and September, and high flows between October and May. Consequently, with adequate installation and transmission facilities, the maximum amount of generation is available for high marketability use.

NORTHWEST POWER POOL

UNDOUBTEDLY MOST of you are familiar with the Northwest Power Pool, which is a flexible operating organization through which all 11 major generating utilities contribute their generation and transmission facilities to the maximum advantage of the region as a whole. The Columbia River Power System transmission network, as constructed and operated by the Bonneville Power Administration for marketing power generated from all Federal Projects in the region, is the arterial system which permits the present highly efficient pool operation and is the principal facility for transmitting energy generated at the Bonneville and Grand Coulee Projects.

The present complex pool network is the result of a series of interconnections begun as early as 1918. It reached its present high level of development in 1942 when the Bonneville Power Administration lines were tied into the system. In addition to making it possible to increase the capacity of the system by a substantial amount, its other advantages are the reduced effect of outages, improved maintenance schedules, and conservation of fuel supplies.

Although I wish to place primary emphasis on the generation of hydroelectric power in connection with the water resources of this area, one should not overlook the great importance of the proper planning and construction of the complex transmission network to bring the power generated to the major load centers. Very close working relationships must be, and are, maintained with the Bonneville Power Administration, and other interested agencies, in order that maximum co-ordination of generating facilities with the transmission network can be achieved.

Obviously, when one contemplates the development of a project or groups of projects, the question of their use must be carefully considered. In the case of large hydro developments, it then becomes necessary to determine the marketability of such energy and where it is to be served. Therefore, in connection with our Review Report, the Bonneville Power Administration prepared a very complete analysis of the regional power requirements. Although it is difficult to forecast what the future holds, a good estimate generally can be made for the next 15 to 20 years. With this in mind, it was estimated that the peak load which the Federal System must serve in this region would be approximately 10,000,000 kw with an average energy generation of around 7,500,000 kw.

In arriving at these values allowance was made for non-Federal generation to date and also for some 750,000 kw in the non-Federal expansion program of which a large block is now under construction.

PHASE C LEVEL SYSTEM

OUR AIM TO achieve a balanced comprehensive multiple-purpose plan for providing adequate flood control, recognizing the expanded irrigation program, and the related power program, resulted in the establishment of a basin development commonly called the Phase C level. The *308* Report investigated several alternative Phase C level systems, and the one recommended to achieve the objective for the region is known as the Phase C-2 system.

Let me review the basis of our *308* investigation that led to the adoption of the Phase C level of basin development. The development of water resources in the Columbia Basin was examined in a series of stages or levels, each of which constituted an advance toward the complete regulation of the Columbia River flows from the power standpoint. Generally speaking, five levels called Phase A, B, C, D, and E were examined. Phase A dealt only with the existing Bonneville and Grand Coulee projects; Phase B added projects then authorized or under construction; Phase C also added those projects that would permit the attainment of the multiple-purpose objectives which could be recommended for early development; Phase D considered many projects which are subject to more study, that appeared economically feasible, in order to give some indication of where additional generation may come from in our long-range planning program; and Phase E is likely to be obtained only in the remote future.

Formulating a workable program for the Phase C level of basin development required a group of projects that would be economically sound, not only for meeting the 10,000,000-kw load requirement, but would satisfy, in conjunction with nonpower developments, the other major multiple-purpose needs of the basin, including flood control, navigation, and irrigation.

As already noted, flood control reservation and power storage use can be co-ordinated. The obvious solution of the flood problem is a combination of storage space and a levee system. The storage space is required at critical points throughout the basin to impound and control the runoff to certain stages with the levees providing the remaining protection.

Since hydroelectric power is, and most likely will continue to be, the predominant source of energy in this region for some years to come, it required little study to determine that the most economical plan of development must have storage which can be released for firming up the low water flows. In other words, the ideal situation is to maintain a well-balanced group of power developments that comprise both run-of-river and storage projects.

It is well known that prior to construction of the Grand Coulee reservoir the low water flow at Bonneville was about 40,000 cubic feet per second, whereas the Coulee storage now would provide an average minimum flow at Bonneville of around 60,000 cubic feet per second. Of course, the Grand Coulee storage has supplemented the flow in low runoff months. Any additional storage must add its effect over a much longer period.

Because hydro is the predominant source of energy in this area, the only amount assured of a firm market is that which can be developed 100 per cent of the time. Careful records have been kept for the Columbia River at The Dalles, Oregon, since 1878, and at other critical points throughout the basin for shorter periods.

In determining the continuous power, examination of the runoff records indicated that the period from 1928 to 1942 was only a little more than 85 per cent of the long-term mean. During this 15-year period the area experienced the lowest runoff winter of record in 1936–1937. It also experienced four consecutive winters, from 1928–29 through 1931–32, each of which was only slightly better than 1936–1937, and with relatively low runoff during the spring and summer months. These runoff data indicated that when a measurable degree of storage was developed, the historical runoff period dating from 1928 to 1932 would control the region's continuous power. In order to develop the region's resources from the long-range point of view, most storage sites will have, within economic limits, hold-over storage. Only Grand Coulee and Albeni Falls do not have hold-over storage.

Consequently, continuous power for Phase A and B levels of basin development are controlled by the 1936–1937 critical hydro year, and Phase C level by the 1929–1932 critical hydro year. With ultimate developments of the Phase D level, the critical hydro period will extend over 42 months from September 1928 to March 1932.

Since the Phase C level must be obtained to meet continuing load requirements within the next 15 to 20 years, the Corps of Engineers uses the 1929–1932 critical hydro period when measuring the economic feasibility of the projects in the Phase C level. Only by recognition of this longer period is it possible to properly assess the value of each storage development with respect to the amount of hold-over storage it possesses.

It has been stated that the hydroelectric resource of the Columbia River and tributaries feasible of development, including the Canadian portion, would be in the neighborhood of 35,000,000 kw of firm capacity, with some 25,000,000 kw of continuous power. Of this continuous power, the Phase C level of basin development will furnish approximately 10,000,000 kw of which about 7,500,000 to 8,000,000 will be Federal and 2,000,000 to 2,500,000 non-Federal. Completion of the Phase D level projects in the United States will add another 5,000,000, and the Phase E level projects will add some 2,000,000 to 5,000,000 kw. The remaining portion, of 5,000,000 to 8,000,000 kw, must be produced through development of Canadian storage and hydro and remaining hydro power sites in this country.

Possibilities for power, and probability of achievement of storage development in the long-range planning program, constitute a critical area in our immediate planning that is very difficult to assess. For example, the size of our power plants at projects on the main stem of the Columbia are materially affected by the amount of storage in the long-range program. If we knew for certain that Canadian storage would never be developed we would modify our system accordingly. In general, this would require over-development of some of our tributaries in this country and increase the number of units at the power projects on the main stem of the Columbia River. Definitely, we would have to look forward to less control of the runoff and thereby would have to depend to a greater extent on some other source of energy to firm up the secondary hydro.

However, this would not necessarily be the best balanced plan for basin development. Since there appears very little reason to believe the Canadians will not develop their Columbia River hydro, all of our long-range planning has been based upon the assumption that the Columbia River Basin will be developed ultimately as a complete unit as if no international boundary existed.

POWER PLANT UNITS

A MOST IMPORTANT problem that arises whenever we initiate construction of a power project is determining the size and number of units of the power plant. This decision affects the entire layout of the structure and in some cases partially controls the site selection. Generally speaking, in developing any site, it is done so as to allow as much flexibility as possible for future expansion of the power plant. For instance, we are planning on a power structure at The Dalles with 22 units, of which 16 are foreseeable under the Phase C level of basin development. The remainder will only be skeleton structures that can be completed when found necessary for future development of storage, or changed system load characteristics. In addition, the layout of the plant has been designed so as not to bar the possibility of adding another four to six units should it be found economically desirable to do so in the future. Thus we seek to retain as much flexibility for plant expansion as possible in order to overcome the many unknown factors that the future may unfold.

INDIVIDUAL PROJECTS OF PHASE LEVEL

BONNEVILLE AND Grand Coulee are, of course, existing projects, with the 18th and final unit at Grand Coulee scheduled for early installation. Combined name plate rating of these two plants is slightly less than 2,500,000 kw.

The Hungry Horse project, currently under construction by the Bureau of Reclamation, is scheduled to have some storage available and one 71,250-kw generator in operation in the fall of 1952; the completed installation of four units is scheduled for November 1953. The ultimate 2,980,000 acre-feet of usable storage will be available in September 1954.

At McNary Dam work is under way on the $60,000,000 completion contract, with two units totaling 140,000 kw scheduled to go on the line in December 1953. Present plans contemplate an ultimate installation of 14 unit (980,000 kw) which should be completed by December 1956. McNary is, of course, a run-of-river project similar to Bonneville.

Chief Joseph Dam, the project next downstream from Grand Coulee, is now well under way. Four 64,000-kw units are scheduled for operation by December 1955, with the initially planned total of 15 units on the line by Sep ember 1958. This project is also of the run-of-river type, out it will serve to iron out the irregular discharges from Grand Coulee when that project is operating as a peaking lant for the system.

The Albeni Falls project on the Pend Oreille River is also well under way. Its total usable storage of 1,140,000 acre-feet is scheduled for use in August 1952. Its power nstallation of three 14,200-kw units is scheduled for completion between August 1954 and April 1955.

The foregoing six projects, either completed or under construction, constitute the backbone of the Phase C level. In addition, there are a number of other projects that will be required to furnish the degree of flood control as well as the necessary generation to meet the load requirements estimated for the next 15 to 20 years. Orderly planning, design, and construction must proceed rapidly if we are to keep pace with the demand for electric energy. The following projects have been authorized by Congress, but funds have not been appropriated for their construction.

Libby, on the Kootenai River, will have a usable storage of approximately 4,600,000 acre-feet and an installed generator capacity of 618,000 kw in six units. Libby storage is very valuable because it is nearly all annual storage and, hence, is dependable for firming up the system during each winter low flow period. It will also control damaging floods that occur almost annually in the Kootenai valley, and reduce peak stages on the lower Columbia.

The Dalles project is another run-of-river installation. As I stated earlier, it may have sixteen 78,000-kw units in the Phase C level—certainly not less than 14 units. Its ultimate installation will depend somewhat on the extent to which it is used as a peaking plant, as well as on the amount of upstream storage that is developed.

In the Priest Rapids project, on the Columbia downstream from Chief Joseph, we propose to install 23 53,000-kw units. It will be designed so that its pool level may be raised sufficiently to provide 2,100,000 acre-feet of flood control storage. Normal operation of this plant for power purposes will not utilize the higher pool level.

The John Day project, which is on the Columbia between McNary and The Dalles, also will function as an important element in the flood control program. Enough surcharge will be permitted to provide space for 2,000,000 acre-feet of flood control storage. Generation facilities will include 13 85,000-kw units.

On the lower Snake River, we have authorized projects scheduled at Ice Harbor, Lower Monumental, Little Goose, and Lower Granite. These dams are run-of-river projects and when the Phase C level is completed, will permit slackwater navigation from Bonneville to Lewiston, Idaho. Initially planned facilities for these sites include four generating units each, with a total installed capacity of 980,000 kw.

In addition to these projects, the Bureau of Reclamation has nine projects existing, authorized, or proposed in the upper Snake River Basin, whose combined installed capacity is 287,000 kw. These projects are operated primarily in the interest of irrigation. However, they do contribute materially to the system power generation.

The Willamette Basin has nine projects, under construction or authorized, with a combined installed capacity of 387,000 kw. Presently under way are Detroit, with two units of 50,000 kw each, and Big Cliff with one 18,000-kw unit, all scheduled to be in operation by December 1953. Lookout Point, with three 38,000-kw units, is scheduled for July 1954 with Dexter and Hills Creek scheduled for early construction. In addition, there are projects to be constructed at Green Peter, White Bridge, and Cougar. All projects are designed primarily to serve in the reduction of flood damage in the Willamette Valley. They also will assist materially in meeting the Willamette Valley energy requirements.

There are two other projects required to complete the Phase C level. Glacier View or a suitable alternate was recommended along with the other projects of the Main Control Plan. However, conflicting interests which have not been resolved have caused the Corps of Engineers to investigate suitable alternate sites in order to assure adequate storage reservation for flood control.

The remaining project, and a very essential element in the Main Control Plan, is Hells Canyon. It has not yet been authorized, but the Bureau of Reclamation contemplates 3,880,000 acre-feet of usable storage and eight 100,000-kw generators on completion.

These projects would comprise the Phase C level of development. Assuming that our estimates of load growth are reasonably accurate, all of the projects will be required within the next 15 to 20 years, if the energy is to be available as needed in the region.

FLEXIBLE PROGRAM

The Corps of Engineers' comprehensive water resource development plan, fully co-ordinated with the Bureau of Reclamation's plan for development of the Columbia River Basin, is a flexible program. All of our projects have been discussed individually at public hearings in various localities where the respective projects are located. It is a pliable program which may be changed in any part as the best interests of the region may dictate. The speed of development and the order in which construction of the various recommended projects is undertaken will be decided by Congress, by and with the advice of the people of the region to whom that deliberative body is responsive.

In order to better familiarize the people with the program's objectives, the Columbia Basin Inter-Agency Committee—the organization which, as you know, includes representatives of all Federal agencies concerned with development of the region's resources, and the Governors of the basin States—will hold public hearings in November. The main purpose of these hearings is to determine the public's collective views on various elements of the program, some parts of which are seriously out of balance, in the interest of effecting adjustments and harmonizing conflicting views. We believe much faster progress will be made once the public's full understanding and unified support of the program is assured. With this public support and region-wide unity, we can proceed with confidence that development of all our resources will keep pace with the rapidly growing Pacific Northwest and be what the people of the region desire.

Metallic Rectifiers in Telephone Power Plants

D. E. TRUCKSESS
MEMBER AIEE

THERE ARE many uses of metallic rectifiers in telephone power plants where rectifiers are required. These applications vary from 2 to 2,500 volts and in power sizes of a few watts to 10 kw. The metallic rectifiers are used primarily for charging storage batteries. However, there are many applications where the d-c power is used directly to supply relay circuits, talking battery, plate and filament for vacuum-tube amplifiers, telegraph circuits, and teletypewriters.

The principal advantage of metallic rectifiers over hot-cathode diode or triode tube rectifiers or the mercury-pool rectifiers, in larger sizes, is that the rectifying element is not an expendable part. This feature is desirable particularly when the rectifiers are located in private branch exchanges (PBX) and small central offices where a maintenance man is not in attendance at all times and reliable operation is important.

The disadvantages of metallic rectifiers are that they usually require more space than tube rectifiers, and they also are more sensitive to the higher ambient temperatures. The metallic rectifier usually results in a higher first cost but often the annual charges are less when the cost of replacing tubes is considered. The metallic rectifiers do not lend themselves as readily to automatic regulation as thyratron rectifiers. However, with the use of saturable reactors and magnetic amplifiers to control the alternating voltage applied to the stacks, a regulated metallic rectifier can be built. This combination makes it possible for regulated metallic rectifiers to compete on an annual charge basis with regulated tube rectifiers, up to 10-kw sizes in the voltage range below 150 volts.

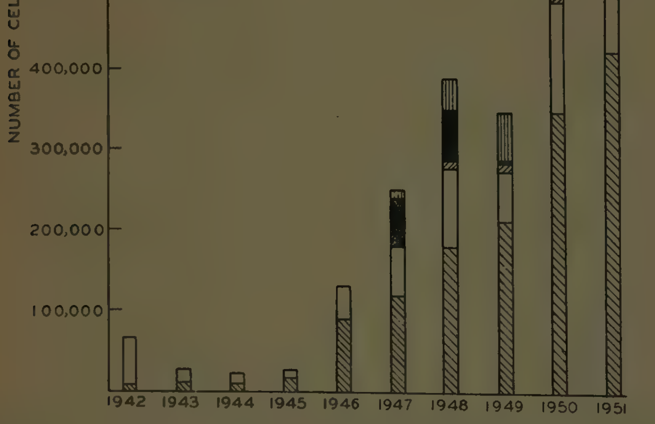

Figure 1. Annual demand for selenium rectifier cells (figures for 1951 are estimated)

Copper oxide rectifiers were first used in the Bell Telephone system in 1927 to trickle-charge PBX storage batteries. During the early 1930's a number of applications for small rectifiers were developed to supply talking battery to station wiring plans for local telephone intercommunication, to trickle-charge large storage batteries, and to supply 24 volts for relay operation. Six equipment arrangements of rectifier units are being used. All of these rectifiers use the $1^{1}/_{2}$-inch diameter copper oxide cell in series and parallel combinations. These rectifiers require about 200,000 cells per year.

Selenium rectifiers were first used in 1942 to supply line current and power for operating the magnets in teletypewriters. After the war selenium found an increasing application in telephone power plants. The early use was of the small size cells from 1 to $4^{3}/_{8}$ inches in diameter. As larger size cells became available they were used in the higher powered rectifiers.

For automatically charging 24-volt batteries in PBX's and to supply filaments of repeaters, selenium rectifiers with magnetic regulation are used in several current sizes. This type of regulation is expanding rapidly to higher voltages and current sizes up to 30 amperes. For larger sizes the saturable reactor type of control is used to obtain regulation. The saturable reactor is driven by an electronic voltage amplifier. The electronic amplifier is required where a closely regulated voltage of ±1 per cent is needed. This type of regulation is used in 12-, 24-, and 48-volt rectifiers used to float storage batteries. They are built in 100- and 200-ampere sizes. Twenty-eight different equipment arrangements are used in telephone power plants requiring about 700,000 selenium cells per year.

Figure 1 shows the annual demand for the $1^{1}/_{2}$-, $2^{3}/_{16}$-, $3^{3}/_{8}$-, and $4^{3}/_{8}$-inch size, and the $4^{1}/_{4}$- by 6-inch size cells. Notice the shift from the $4^{3}/_{8}$-inch size to the larger cell.

The experience with selenium rectifiers has been very good. Sufficient time has not elapsed to know whether they will last as long as copper oxide rectifiers. However, the selenium rectifier applications must be made with great care to insure that they do not operate in too high an ambient temperature, that they operate at the proper current density in each cell, and that their rated voltage is not exceeded. It is important that the inverse peak voltage applied to the cells be controlled carefully as there is very little safety factor and in some cases surges or a distorted 60-cycle wave shape may produce selenium failures.

Digest of paper 51-273, "Metallic Rectifiers in Telephone Power Plants," recommended by the AIEE Committee on Metallic Rectifiers and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Toronto, Ontario, Canada, June 25–29, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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The Economic Factors Which Influence Dieselization and Electrification

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The choice between diesel-electric and straight electric motive power for railroads depends on a number of economic factors. The differences between these two types, and the reasons for selecting one over the other, are given in this article.

THE DIESEL-ELECTRIC locomotive has been adopted extensively for new motive power purchases in North America. In many other regions throughout the world—South America, Australia, Europe, Africa, India—electrification has been selected for operation of major railway systems. These differing trends have led to speculation concerning the economic status of these two types of motive power. This article briefly explains the reasons which have led to these diverse decisions, and attempts to show that they are the logical result of conditions which currently prevail in various parts of the world.

The remarkable developments which have taken place in the electric drive have shown its superiority to the reciprocating steam locomotive to be so great that the trend today is almost exclusively towards some form of locomotive incorporating the electric drive. Locomotives utilizing the electric drive may be powered by diesel engines, steam turbines, gas turbines, or by overhead trolley systems fed from large central stations. For purposes of this discussion, the diesel-electric and electrification only are considered because the turbine locomotives, either steam or gas, have not received wide commercial application.

Since the diesel-electric and the straight electric locomotive both employ electric transmission of power to the driving wheels of a locomotive, they have, or can be made to have, many identical characteristics for haulage purposes which are superior to the characteristics of the reciprocating steam locomotive. The main difference in these two types lies in the primary source of power for the electric drive. Three major differences exist between these two types of locomotives.

1. The diesel-electric locomotive, which must carry its own prime mover, is definitely limited in horsepower output by the capacity of this prime mover, and by the limitations placed on this capacity from weight and clearance restrictions which will differ widely on rail systems throughout the world. The electric locomotive, which receives power from large stationary power sources, is not subject to these same restrictions. Consequently, higher horsepower electric locomotives can always be produced, providing a higher standard of rail operations within the same weight and clearance restrictions.

2. Diesel operation must carry the maintenance expense which accompanies a multiplicity of small mobile prime movers, while electric operation, when electric energy is purchased, avoids this expense. The maintenance of these prime movers comprises 40 to 50 per cent of the total diesel locomotive repair cost. The maintenance expense of the electric locomotive, including a pro-rata share of the distribution system, should be lower when the mobile prime movers are eliminated.

3. Electrification provides a broader range of possible fuels. Electric energy may be produced from residual oils, natural gas, or coal in large steam stations, and in many localities from water power. On the contrary, diesel operation is restricted to diesel fuel which is often in scarce supply and high in price. When available sources of fuel are restricted in volume or in kind, electrification will provide an insurance against fuel shortages or adverse prices.

Beside these basic differences in the two types of motive power, there are many others, of a nature peculiar to specific localities or countries, which may have a very controlling influence on the adoption of either diesel or electric motive power.

DIESELIZATION IN NORTH AMERICA

THE WIDESPREAD adoption of the diesel-electric locomotive by the railroads of North America has created the impression, in some quarters, that railroad electrification is an obsolete form of motive power. An analysis of the conditions which brought about this dieselization does not necessarily substantiate this conclusion.

Most major railroads in North America are privately owned corporations which must have profitable operation for their existence. At the close of World War II, these railroads were faced with rapidly rising operating expenses which were not accompanied by a proportionate increase in operating revenues, a combination that produced a very unfavorable operating ratio. Motive power on the railroads consisted predominantly of reciprocating steam locomotives whose operation was handicapped by rising fuel costs, and even worse, by labor troubles in the coal

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industry which caused, on several occasions, serious curtailment of railroad operations and threatened continuation of railroad service. These conditions forced the adoption of a new type of motive power capable of being installed in a short period of time, a type which would provide immediate operating economies and immediate relief from troubles incident to the use of coal as the major railroad fuel. The diesel-electric locomotive was the logical answer to the problems which beset these railroads.

The diesel, by its use of the electric transmission, provides a locomotive capable of delivering constant horsepower at the rail over the normal working range. This speed-tractive effort characteristic permits larger trains to be hauled on faster schedules, eliminates "double-heading" of locomotives, and reduces helper service. These provide operating economies of considerable magnitude. They are the operating benefits of any locomotive which incorporates the electric drive.

The diesel-electric locomotive lends itself to a high degree of standardization, allowing production of a few models. American industry was prepared to produce this type of locomotive in large quantities. The diesel, therefore, met the demand for a better locomotive which could be produced in a short period of time and which could be operated without demanding extensive changes to the roadway and other railroad fixed property.

The tremendous distances spanned by the main line railroads of North America have been an obstacle to extensive electrification and have worked to the adoption of the diesel. To secure the greatest benefits from any type of motive power on these far-flung systems, it is necessary to operate locomotives on long runs. In the case of electrification, this would require installations extending over several hundred or thousands of miles of line. Such installations naturally involve expenditures of great magnitude, especially if detour routes are provided for emergency conditions.

Where railroad systems are privately owned corporations, funds for improvements must be secured from private banks, insurance companies, or by the sale of securities to the public. The credit of many railroads was not sufficiently sound to secure the large funds required for major electrifications at favorable interest rates due to the nature of the credit situation which exists under private ownership.

Locomotives themselves can be purchased on equipment trust loans where the only security offered to the lender is a mortgage on the locomotives purchased. These loans have enjoyed such prestige that money can be readily secured in this manner. More recently, insurance companies have purchased locomotives for rental to the railroads, the latter being under no obligations other than periodical rental payments. With these methods of financing, locomotives are readily securable by any privately owned railroad, more or less regardless of its financial condition, because locomotives can be reclaimed and resold should a railroad default on its payments.

The wayside facilities, trolley transmission lines, and substations, which are a part of all electrifications, cannot be financed in North America in the easy manner available for locomotive purchases. Money for this type of apparatus requires the sale of bonds, secured by a mortgage on the railroad. This increased fixed indebtedness is not welcomed by any railroad which has been financed by private capital.

Of all factors influencing motive power developments in North America, the fuel situation is probably paramount. This region is fortunately blessed with an abundant amount of diesel fuel which can be secured in practically all sections at a reasonable price. On the contrary, electric power, in the regions through which the densest rail traffic moves, is produced predominantly from coal, a fuel which has risen rapidly in price and has been subject to serious shortages.

One of the past economies of electrification in North America has been a substantial saving in fuel expense, especially comparing electric operation to steam operation. Today, diesel oil can be secured for 8 to 11 cents a gallon almost universally throughout the country, while electric power produced from coal costs 0.8 to 1.0 cent per kilowatt-hour if exceptionally good load factors are secured, and may be even higher if purchased under adverse conditions. With these prevailing prices of diesel oil and electric power electrification cannot show economy in fuel expense. This particular relationship between these two major sources of energy does not exist in other parts of the world except in limited cases.

There is no evidence that North America will be faced in the immediate future with a shortage of diesel fuel for railroad operations or with a marked increase in its price. In contrast to this ample supply of diesel fuel, the nation has faced a shortage of electric power continuously since the conclusion of World War II. This shortage has been so serious that the electric power industry has not been in a particularly favorable position to assume major loads such as extensive railroad electrifications. In spite of the greatest expansion of the power industry in history during the past five years, a shortage of power has existed.

In the past decade the railroads of North America have been forced to find an economical type of motive power to replace the reciprocating steam locomotives. The type of motive power selected had to be one of proved economy, one which could be produced rapidly, one which could be readily financed without impairing railroad credit, and one which operated on an abundant, inexpensive, and readily available fuel. The diesel-electric locomotive met these conditions for the privately owned railroads and has revolutionized railroad operations in North America.

MOTIVE POWER OUTSIDE OF NORTH AMERICA

The conditions which have made the diesel imperative for the railroads of North America do not exist to a similar extent in many other countries.

In spite of its operating advantages, the diesel-electric locomotive would never have reached universal acceptance in North America if that region had not had an abundant supply of oil, with an assured source of supply under all world conditions and with a favorable price level.

A comparison between current fuel prices in the United States and those in a foreign country having an extensive electrified service is representative of the different conditions which may exist throughout the world:

Relative Fuel Costs, United States and Foreign Country

	United States (Dollars)	Foreign (Dollars)
Coal per ton (2,000 pounds)	5.34	16.80
Diesel oil per gallon	0.0909	0.161
Electricity per kilowatt-hour	0.01061	0.00667

With these fuel prices, the relative cost of producing 100 horsepower hours of useful work at the locomotive driving wheels is as follows:

Relative Cost per 100 Horsepower Hours, United States and Foreign Country

	United States (Dollars)	Foreign (Dollars)
With coal	1.06	3.38
With diesel oil	0.80	1.43
With electric power	1.06	0.67

In the United States the average cost of electric power is 133 per cent that of diesel oil, while in the selected foreign country it is only 47 per cent that of diesel oil. In other words, the fuel situation in the foreign country is roughly $2^3/_4$ times more favorable to electric operation. Conditions similar to these might be cited for other countries which have limited coal and oil resources.

The fuel situation, price, availability, and assurance of supply must be a paramount consideration in any selection of motive power. In any area without an assured supply of oil, electrification offers the widest protection against all uncertainties in sources of fuel for railroad operations. Again, in most countries where a questionable supply of oil exists or where its price is relatively high, electrification will produce a marked operating economy in the operation of heavy traffic rail lines.

Besides economies in fuel, electrification will show other savings, generally speaking, compared to the diesel. Locomotive maintenance should be lower on the straight electric locomotive because the mobile prime movers are eliminated. On most railroads outside of North America smaller trains are operated. The number of locomotives owned per mile of railroad is greater, producing a proportionately increased economy in locomotive maintenance by the avoidance of locomotive prime movers.

Most railroads of the world, exclusive of North America, are built for maximum loads per axle of 35,000 to 40,000 pounds against 60,000 to 65,000 in North America. It is a more difficult problem to build high-capacity diesel-electric locomotives for these roads with weight, clearance, and gauge restrictions. On the other hand, high-capacity electric locomotives, which do not carry their own prime movers, can be constructed for operation under these restrictions. Wherever the desire exists to produce a very high standard of service under restricted loadings and clearances, the advantages of electric power become more pronounced. Electric locomotives have been constructed to produce 4,000 rail horsepower per 100 tons on drivers while no American diesel has yet exceeded 1,650 rail horsepower per 100 tons on drivers.

Generally speaking, rail systems outside of North America do not extend over comparable distances. Because of this fact, it is often possible to reap the benefits of electrification through rather modest investments for installations of relatively small mileage. The nature of the traffic, supplemented by a higher percentage of locomotives per mile of track, makes electrification a more lucrative investment. As most foreign rail systems are government-owned, the peculiar financial problems incident to North America do not exist.

The diesel locomotive was made practical by standardization. There has always been a reluctance to standardize electrification systems and their component parts. The economy of electrification could be greatly improved if the railroads would permit a greater degree of standardization, not only as it pertains to trolley voltage, but also motive power. The manufacturers of electric motive power and machinery would welcome standardization. The railroads should reach agreement on a few basic standards and cease preparing difficult specifications to suit some fictitious requirement. This practice has ceased with the diesel, otherwise present prices could never have been attained. The principal need in railroad electrification is to find means to reduce first cost, and if this can be made possible the field for its economical use will be expanded.

GENERAL SUMMARY

WHEREVER IT CAN be economically justified by traffic density or favorable fuel sources and prices, electrification remains, as it has in the past, the finest method yet devised for operation of the world's major rail systems. By its use a higher standard of service can be produced, the maintenance expense lowered, and, in many parts of the world, a decided economy affected in the cost of fuel or energy. Unfortunately, conditions in North America have made it impossible to expand electric operation. The trend in this area, nevertheless, should not prejudice the views of railroad management elsewhere who must operate under radically different economic conditions.

At the moment, two types of power are available with assured background of experience, the straight electric and the diesel-electric. Each type can be built to give a most creditable performance. The important factor is to see that each is applied where conditions are suited for best over-all economy.

In closing this discussion of dieselization and electrification, mention should be made of the gas turbine. In the not too distant future, this type of electric locomotive may be available for general application in road passenger or freight service. It offers certain promising features, especially an ability to burn residual fuels and possibly coal. Its major characteristics as a motive power unit will closely follow those of the diesel, and its widest applications appear to be in services now handled by the larger diesel road locomotives. Where electrification now is justified in comparison with the diesel, it likely will be justified in comparison with the gas turbine.

An Analogue Computer for Cable Temperatures

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THE CALCULATION of temperature transients in cable systems under a stated condition of loading which may be either variable or constant is a complicated procedure involving the application of a high order of mathematics.

This mathematical complexity results from the fact that under transient conditions the thermal capacity as well as the thermal resistance of the components of the thermal circuit must be considered. By analogy to electric circuit theory, thermal capacity may be represented by electrical capacitance, thermal resistance by electrical resistance, temperature by voltage, and heat flow by electric current. Thus, a given thermal problem may be solved by setting up the electrical counterparts properly proportioned in a network, applying a current proportional to the heat flow, and reading the voltage developed at any part in the network after a time interval proportional to the corresponding time interval in the thermal system.

In formulating such a network representative of a buried cable system, those components which have distributed thermal capacity, such as the insulation and the earth, may be represented by one or more sections in which the capacity of the section is considered to be lumped at the median diameter of the section. In thus representing the earth, the use of the large amount of electrical capacitance required to set up the earth portion of the thermal circuit is avoided by setting up only a part of the earth network. It may be shown that the temperature rise across that portion omitted may be calculated for any given condition of heat flow and added to the corresponding temperature rise determined by electrical means across the equivalent network set up.

The schematic diagram of a simple analogue computer designed for this purpose is shown in Figure 1, consisting of an adjustable resistance-capacitance network, a current control system, a vacuum-tube voltmeter, an electronic timer, and a suitable power supply. The vacuum-tube voltmeter serves to measure the voltage developed at any point without drawing any current from the network. The electronic timer offers a means of disconnecting the voltmeter from the network at any desired time during the transient, and the voltage measured at the instant of disconnection is held on the small capacitor C_2 associated with the voltmeter until the meter can be read.

The network current is held constant by a pentode vacuum tube and its value is set by the variable resistor R_2.

When desired, the current may be varied in accordance with a given loss cycle by means of a 24-point stepping relay and a plug board on which the relative current value for each step may be set.

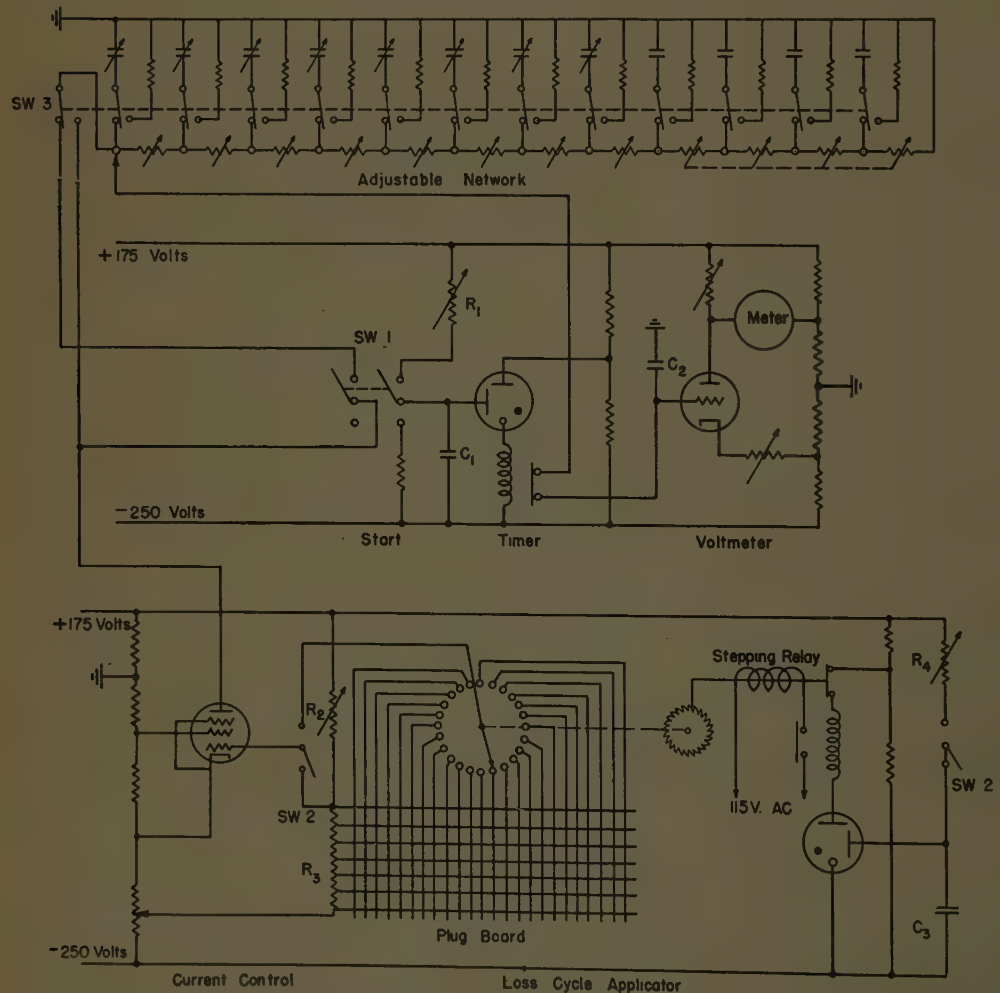

Figure 1. Schematic diagram—analogue computer for cable systems

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Digest of paper 51-253, "The Determination of Temperature Transients in Cable Systems by Means of an Analogue Computer," recommended by the AIEE Committees on Computing Devices and Insulated Conductors and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Toronto, Ontario, Canada, June 25–29, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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Electric Shock

WILLS MACLACHLAN
FELLOW AIEE

The study of the effects of electric shock on living animals has been pursued for over 200 years. The author reviews the literature which has been written on the subject, discusses animal experimentation and actual field cases, and draws definite conclusions.

WHILE A LINE CREW is extending a secondary circuit, the wire catches on a bush. On being pulled, the wire whips up and makes contact with the primary alive at 4,000 volts. A lineman in contact with the secondary wire has his feet in contact with a ground and receives a severe electric shock. He stiffens up, then relaxes and hangs in his belt. He is unconscious, is not breathing, and no pulse can be felt at the wrist.

What has happened to this man as the result of the passage of the current? What remedial measures can be put into effect to save his life? A review of the literature on the subject may help to answer these questions. Animal experimentation can assist if care is exercised in translating results from animals to man. A study of experience from actual cases in the field is also of assistance. The present discussion will endeavour to cover these points and draw definite conclusions. The problem of high-frequency circuits and that of therapeutic currents will not be considered to be within our general problem.

The study of the effect of the passage of electric current through living animals has been pursued for over 200 years. "A Report on Some Electrical Experiments on Fatal Injury Caused by Electric Sparks" by Daniel Gralath was published in Danzig, Germany, in 1747. From this report it is evident that much work other than that of Gralath was being done on birds and small animals, as well as shocks given to people from friction machines and Leyden jars. An attempt was made to compare the effects obtained to the known effect from lightning. Note that this report was published in 1747.

General reviews on the subject of the effect of the passage of electric current through man have been published in Europe and America. One of the most outstanding is that of A. J. Jex-Blake,[1] published in 1913. In this, after reviewing the knowledge up to that time, he emphasizes both the occurrence of cessation of breathing and a heart effect. He recommends the prompt application of artificial respiration and its continuance until the patient breathes of his own volition or there are definite signs of the onset of rigor mortis. Professor Stefan Jellinek,[2–4] writing in Vienna, Austria, has presented a classic review based on field experience with electrical cases and on autopsies. His outstanding work on electric burns is outside our general problem. After reviewing all of the theories of the causation of death from electric shock, he claimed that it was best described as "apparent death" and recommended the prompt and continued application of artificial respiration. He discounted the effect on the heart that had been described by Prevost and Battelli.[5–10] These observers claimed that in most cases of electric shock the heart of the victim is thrown into ventricular fibrillation that is, a quivering of the heart which does not permit it to pump blood. This argument will be expanded later in greater detail.

Jaffé's[11] review deals more particularly with the pathology of electric shock and is one of the best that has been published in the United States.

These general reviews mention the fact that certain people can withstand a more severe shock than others; that at certain times a person can withstand a more severe shock than at other times. All agree that stopping of breathing is one effect of the electric shock. Some people suggest ventricular fibrillation as the most general and dangerous effect of electric shock. Other people frankly deny this theory.

EFFECTS FROM MINIMUM CURRENTS

THROUGHOUT THESE REVIEWS the hazard of low-voltage shock is stressed. The Electrical Testing Laboratories[12] reported in 1918 a test on 14 men in order to discover the amount of current they could tolerate using a grip contact. They found this to be maximum 12.4 milliamperes, average 6.3 milliamperes, and minimum 2.7 milliamperes. Gordon Thompson[13] of the Electrical Testing Laboratories based his article of 1933 on further tests on 70 men and women, showing that perception of shock varied from 0.34 milliampere to 1.18 milliamperes for tap, pinch, grip, and immersion contacts, the resistance varying from 37,500 ohms to 1,540 ohms, and the voltage drop across the person from 12.5 volts to 2.3 volts. In these tests they found the intolerable current (see Dalziel[14] "let go current") to average 7.1 milliamperes. While it is true that the current is the absolute gauge of the severity of the shock, yet in actual cases the voltage of the circuit or apparatus is the only measure known. It is therefore interesting to see the statement of the Electric Works, Zurich, Switzerland,[15] that danger to life exists where potential exceeds 30 volts for dry hand contact, 22.5 volts for wet hand contact, and 11.3 volts for contact of a body in a bath. In demonstrating to a large number of linemen in Ontario, Canada, the small amount of current that they could take without great pain using wet grip contact, it was found that

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few could take a shock of over 11 volts. Many linemen's hands are normally quite damp even in cool weather.

In practically all of these tests the person was aware that the shock was to be applied. This is not so in accidental shocks, and tests show that the shock even in linemen is more severe if the precise instant of application of shock is not known to the victim. Among the general public, fright cannot be ruled out as a contributing factor.

The hazard of electric shock from ungrounded frames of electric apparatus is ever-present. The voltage gradient around ground wires and water pipes while carrying current and entering the ground or water is always a hazard. There are also well-authenticated accident cases of shocks from voltage gradient through the earth from lightning strokes. In some of these cases the current passing through the body is quite small.

PHYSIOLOGICAL EFFECTS

In 1927 Urquhart[16] showed that with passage of current through the brain the first effect was a stimulation of all centers, followed on the breaking of the current by profound inhibition or paralysis of the vital nerve centers. With the paralysis of the respiratory center, breathing stops. The vasomotor center controls muscles that maintain the tone of the blood vessels and with the paralysis of this center the blood will collect in the large blood vessels of the abdomen. The vagus center controls the rate of the heart and its paralysis results in acceleration of the heart. In the experimental animals artificial respiration brought about the recovery of all cases in which there was no gross damage to the brain or spinal cord from burning at the point of contact. One of the usual tests of the medical profession for life is to flash a light in the eye and watch for the iris to close partially. Immediately after electric shock, Urquhart showed that the flashing of a light in the eye did not close the iris, but that when resuscitation was continued and the various centers had recovered and the animal started breathing the iris closed with the flashing of the light.

Other tests for life used by the medical profession make use of stimulation of a sensory nerve, thus sending a nerve impulse through a center and from there by way of a motor nerve impulse to a muscle which gives an outward observable reaction. If the center is paralyzed as Urquhart has shown, no impulse goes past the center. This clearly confirms the earlier contention of Jex-Blake that in electric shock "nothing less than the cooling of the body or the onset of rigor mortis could be accepted as evidence of death."

In 1929 Urquhart and Noble[17] reported further, showing that the passage of a current through a nerve or the spinal cord could paralyze the nerve or cord or set up a block. They also showed that this block would pass off in time but when the current was increased a degree of block was produced which would not pass off in a reasonable time. They also tested certain suggested aids to artificial respiration and found that "the addition of carbon dioxide to the air used for artificial respiration or the use of oxygen instead of air for this purpose does not hasten the return of normal breathing in electrocuted rabbits. Injection of adrenalin is also of no advantage."

Leo Alexander[18] reports in part as follows:

"Death in the two fatal cases in which the current had passed through the trunk including the heart was primarily due to circulatory dysfunction: extreme contraction of the heart associated with generalized arterial vasoconstriction followed by inhibition of the heart is the most likely chain of events. Whether this inhibition of the heart was associated with ventricular fibrillation or whether it was simple inhibition due to excessive stimulation of the vagus endings could not be decided."

Since ventricular fibrillation in animals following electric shock was reported by Prevost and Battelli,[5–10] many references are made to the effect that ventricular fibrillation occurs with electric shock in man. This is usually fatal but some cases of recovery from ventricular fibrillation in man have been reported although not in electric shock. Some European papers claimed that ventricular fibrillation was responsible for as high as 90 per cent of the fatal electric shock cases.

Jellinek took the view that the cessation of breathing was the important effect minimizing frequency of ventricular fibrillation.

Ettinger[19–22] reports that in cats and rabbits after electric shock a condition of ventricular flutter which was transient was found, or if true ventricular fibrillation was present it ceased and true heartbeats continued. In viewing electrocardiograms of electrocuted criminals which were interpreted as showing ventricular fibrillation, Ettinger felt that they were very similar to the ventricular flutters that he had seen in animals. This problem is by no means solved.

H. B. Williams[23] and others reported on an outstanding series of animal experiments over a number of years. They showed that if a shock of brief duration hit the heart during a particular part of the beat, the heart would go into fibrillation. By the use of heavy currents they were able to countershock animals and in many cases stop the fibrillating heart and restore the heart to normal beats. In an actual field case it would be difficult if not impossible to use the heavy current countershock method. Also, without an electrocardiograph present it would not be possible to diagnose ventricular fibrillation. Work is in progress at present to develop simpler means of detecting and stopping the fibrillating heart.

Sir Frederick Banting[24] and others make the following significant statement in a paper:

"Even though the heart beats are not heard by means of a stethoscope and the pulse cannot be detected, artificial respiration must be continued until rigor mortis sets in. In many of our experiments the cardiac complexes have been detected electrocardiographically for as long as 25 minutes after the heart sounds could not be heard with a stethoscope. Many such observations have been made in human cases. Among others, Birchard has taken electrocardiograms during and after death in a great many cases, and approximately normal electrocardiograms were obtained for upwards of one-half hour after all signs of somatic activity has ceased. Consequently, and this cannot be too strongly emphasized, the stethoscope is probably a poor instrument with which to determine whether or not a person is beyond the point of resuscitation. Prompt, adequate, and prolonged artificial respiration is the only treatment for drowned, asphyxiated or electric-shocked persons."

INFORMATION FROM FIELD CASES

Articles were presented in 1930 and 1934 on field cases.[25,26] After dividing the accidents by the hours worked per month, the 15-year experience of a large utility showed that more severe electrical accidents occurred in May, July, August, and October than in other months. It was interpreted that accidents in May were due to lack of training, those in October to hurry to complete work, and those in July and August to the effects of heat and perspiration. It also was shown that the peak of accidents in the day occur between nine and ten in the morning and three and four in the afternoon. This was confirmed by D. C. Stewart,[27] reporting on a different set of electrical accidents in public utilities. It is also shown that success in resuscitation declines in midsummer and in the midmorning and midafternoon. No satisfactory explanation of these facts has appeared as yet. It is shown also that of victims that received a severe shock, stopped breathing, and fell clear, 71 per cent were resuscitated; where they were cleared by other means, only 42 per cent were resuscitated.

This confirms Urquhart's experience with short duration shocks in animals. Where artificial respiration was started within three minutes, 73 per cent of the cases were resuscitated; when the delay was four minutes or more 14 per cent were resuscitated.

In the group of cases from the large electrical utility, eliminating cases of gross injury such as broken neck, and so forth where there was little or no chance of resuscitation, and arranging according to potential of circuit involved, the following was found:

	Per Cent Successfully Resuscitated
0– 749 volts	50
750– 4,999 volts	40
5,000–39,999 volts	86
40,000–	75
All	64

Recent British[28] experience as reported by the Ministry of Labour and National Service shows the comparison of successful resuscitations from electric shock in factories for the years 1941 to 1948:

	Per Cent Successfully Resuscitated
0– 250 volts	49
250– 650 volts	26
650– 5,000 volts	42
5,000–10,000 volts	58
10,000–	55
All	47

In 1922 the Canadian Electrical Association put up a medal of award for meritorious cases of resuscitation from electric shock by the prone pressure method. Up to November 21, 1950, 136 medals have been awarded. The following is an analysis of the cases by potential of circuit:

	Per Cent of Cases
0– 749 volts	16 (less than 250 volts—9)
750– 4,999 volts	37
5,000–39,999 volts	32
40,000–	9
Lightning	3
Induced voltage	1
No voltage given	3

The information for analysis of American medal cases is not available at the present time.

D. C. Stewart,[29] reporting fatal accidents for the Edison Electric Institute, shows that for the nine years 1941 to 1949, 70.9 per cent of these accidents were electric shock and burn. An analysis of these cases by potential of circuit shows:

	Per Cent of Cases
0– 749 volts	6 (less than 250 volts—5)
750– 4,999 volts	41
5,000–39,999 volts	39
40,000–	7
Induced voltage	1
No voltage given	6

In much of the literature the information is given that in electric shock from low-voltage circuits the effect produces ventricular fibrillation, and high-voltage shocks produce stoppage of breathing. There is no evidence to show that artificial respiration will assist in stopping the fibrillation. The British experience and Canadian experience here first reported and that of 20 years ago show that prone-pressure artificial respiration resuscitated many of these low-voltage cases. It is obvious that in some of the low-voltage cases ventricular fibrillation was not present or was transitory. From the Edison Electric Institute fatal shock information it may be inferred reasonably that few fatal electric accidents occur to electrical public utility employees from low-potential circuits. This statement probably would not hold true in low-voltage shock cases in factories or among the general public. One possible explanation of the low percentage of low-voltage fatal cases might be that many low-voltage cases were resuscitated. This cannot be proved in the absence of American information.

It is clear from the earlier Canadian experience and the British experience that a high success in resuscitation is obtained in high-voltage cases. One explanation of this might be that when the victim brings his hand close to high-voltage circuit or apparatus he comes into the electric field surrounding the conductor, receives a shock resulting in a spasm of the muscles, and is thrown clear. His body may not even come in physical contact with the wire or apparatus. The time of contact is therefore very brief, hence shock is not so severe as with a longer contact at even a lower potential. It might be that the situation is the result of two curves: one increasing severity of shock with increasing potential, thus an increase of current passing through victim; the other decreasing severity of shock with decreasing duration of contact due to increase of potential of circuit. These curves may cross about the potential of primary circuits, say 250 to 4,000 volts, and explain the difficulty of resuscitation in this group, hence deaths.

ARTIFICIAL RESPIRATION

Methods of artificial respiration have come down through the ages. Sir Arthur Keith[30] has presented a masterly review of the methods. In the early part of this century Sir Edward Sharpey Schafer[31–33] put forward the prone-pressure method of artificial respiration. The patient is placed in a prone position and rhythmic pressure and release is applied by the operator's hands on the lower ribs of the victim. In this way the diaphragm of the victim is raised and lowered and the patient caused to breathe.

Since the presentation by Sir Edward Sharpey Schafer, and before, many other manual methods have been put forward—some modifications, some resurrections of earlier methods. Many attempts have been made to test the efficiency of the methods, the most recent being by A. C. Ivy[34,35] and others. These tests for the most part base efficiency on tidal air exchange or air exchange per minute. In electric shock it has been shown that there are other conditions beside lack of breathing and that the addition of oxygen did not assist in the return of natural breathing. Also, it must be remembered that too much oxygen or too fast or too deep breathing will blow off carbon dioxide from the blood, producing a condition of apnea—that is, a suspension of breathing. In the prone-pressure method sufficient exchange of air is provided to maintain life and to restore natural breathing. Since 1922 in Canada and the United States medals have been available for authenticated cases of resuscitation from electric shock by the prone-pressure method or its modifications. Insull Medals awarded from 1922–1934 were 414; Edison Electric Institute Medals 1934–1950, 307; President's Medal National Safety Council (electrical cases) 1928–1947, 247; Canadian Electrical Association Resuscitation Medal 1922–1950, 136. In these 1,104 cases, fully scrutinized and supported by affidavits, lives have been saved from electric shock by this method. It is simple and saves lives.

For at least 200 years various types of apparatus have been put forward to carry out artificial respiration. The first conclusion of the "Report of The Respirators (Poliomyllitis) Committee"[36] reads as follows:

"Breathing machines are required only for protracted failure of respiration. The factor of greatest importance in the treatment of acute asphyxias such as drowning, electric shock, or gas poisoning is the promptitude with which treatment is instituted. No development or multiplication of apparatus can compare in usefulness with the training of all members of the community in manual methods of artificial respiration, and manual methods must never be postponed in an emergency through the mistaken idea that the patient can be better treated in a machine."

In 1917 the Third Resuscitation Commission was appointed. On it were prominent physiologists from Harvard, Yale, Johns Hopkins, and Western Reserve Universities; the Rockefeller Institute; Dr. A. E. Kennelly from Harvard; Professor Elihu Thomson from the General Electric Company; Dr. Charles A. Lauffer from Westinghouse; and men from the United States Army, the United States Navy, the United States War Department, the United States Public Health Service, and the public utility industry. This Commission[37] reported in 1918. The first five resolutions were as follows:

"1. That in most accident cases no resuscitation apparatus is at hand for immediate use.

"2. That reliance upon the use of special apparatus diminishes greatly the tendency to train persons in the manual methods and discourages the prompt and persevering use of such methods.

"3. That police officers or physicians often interfere with the proper execution of manual methods, in that they direct that the patient be removed in an ambulance to some hospital, thus interrupting the continuance of artificial respiration.

"4. That in many hospitals the members of the staff are not all acquainted with the methods of artificial respiration.

"5. That in medical schools instruction is not properly provided for students in the manual methods of artificial respiration."

These findings are as true today as when they were written.

About 1930 the Pole Top Method of artificial respiration was put forward. It had been shown that there was a better chance of success in resuscitation from electric shock if the method was applied promptly. There was delay at times in removing a shocked man from a pole. The plan was for one lineman to get in position on the pole so that he could bring pressure on the abdomen of the victim and so make him breathe. Victims have been resuscitated by this method. One should be careful, however, and recognize that as shown by Urquhart[16,17] there is also a vasomotor paralysis. This means that in a man in a vertical position there is a tendency for the blood to leave the brain and upper parts of the body and collect in the large blood vessels of the abdomen so that the man dies of cardiac failure. Except in extreme cases, rather than the pole top method, every endeavour should be made to lower the man to the ground and place him in a horizontal prone position and continue artifical respiration with the Schafer method.

In training field forces and others it has been found important to have all employees trained so that the closest man to the victim can give immediate relief. In this training it has been found important to explain why as well as how. In an actual case employees are liable to be excited and lose their heads. To overcome this, regular and constant practice of artificial respiration is instituted. Excitement is overcome by habit training.

In the literature one frequently meets the instruction that manual artificial respiration shall be started as soon as possible after shock and continued until a respirator or other apparatus is brought to take over. Why? Trained men can operate indefinitely if not interfered with. They have carried on to success after eight hours of effort.[25,26]

An ideal treatment of an electric shock case is illustrated in the following experience.

In a substation in Kirkland Lake, Ontario, Canada, on October 21, 1936, men were extending a switch and bus structure. Part of the structure was alive; the new part was dead. To reach the work a ladder was used. During the night the ladder had been moved from the dead section to the live section. At 8:25 A.M. a workman climbed the ladder into the live 11,600-volt bus, received a shock, rolled down the ladder unconscious, not breathing, and looked dead. Fellow employees immediately started artificial respiration and called the doctor. After a short time, Dr. D. B. Messenger, who had previous experience in an electrical public utility, arrived and encouraged the men to proceed. The victim started to breathe by himself. The doctor checked his patient's condition and wrapped him in blankets on the substation floor and left two fellow employees to watch him. The doctor returned at half-hour intervals and went over his patient. At noon, he felt that his patient was ready to travel. An ambulance was called and patient taken to a hospital. He made an uneventful recovery from burns. How often do we hear of the patient, before he is breathing, voluntarily being rushed to a hospital with fatal results.

CONCLUSIONS

1. Severe electric shocks can be received from very low potentials and wet contact must be assumed in actual cases.

2. The passage of electric current produces a stimulation of the nerve centers and nerves, and on breaking may produce a paralysis of the centers and possibly a block of the nerve. This results in a tonic spasm of the muscles at first and then relaxation. The breathing stops; there is a tendency for blood to leave the upper parts of the body and collect in the large blood vessels of the abdomen. The heart rate is affected materially. A ventricular flutter or fibrillation may develop. This, some maintain, will pass off of its own accord; others, that the heart must be stopped and then started again.

3. Since there often is a paralysis at the nerve centers after electric shock, the usual tests for life fail and are not dependable. The stethoscope is unreliable after electric shock.

4. Peaks of severe electrical accidents occur in May, July, August, and October, between nine and ten in the morning and three and four in the afternoon. Some cause other than fatigue must be sought.

5. There is a much higher success in resuscitation where the contact with energized circuit is of short duration and when artificial respiration is applied promptly.

6. Many fully authenticated cases of successful resuscitation from low-voltage shocks by the prone-pressure method have occurred. Successful cases are presented also from high-voltage cases. An explanation is offered.

7. The usual method of testing the so-called efficiency of the various methods of artificial respiration is questioned. It has been shown that oxygen inhalation after electric shock is of no advantage and it is possible that too much oxygen may stop the patient breathing. The Schafer prone-pressure method has saved many lives from electric shock in the public utility industry in Great Britain, Canada, and the United States.

8. British and American Commissions endorse manual methods in preference to the machine methods of artificial respiration.

Returning now to the case of the lineman who received a primary shock to ground.

1. The passage of the current has paralyzed the higher nerve centers so that he is unconscious, not breathing; heart is either beating feebly or possibly in ventricular flutter or fibrillation; there is a tendency for the blood to leave the upper parts of his body.

2. Since he has fallen clear, efforts to assist him can be started immediately. If he had not fallen clear, he would have to be cleared from contact as quickly as possible.

3. He is to be lowered to the ground with as little delay as possible and artificial respiration started as soon as possible by well-trained men who have practised monthly. If there will be delay in lowering him, pole top method may be used while immediate plans are made to lower him. If he is not lowered promptly there is danger of cardiac failure due to vasomotor paralysis.

4. He is to be kept warm.

5. Artificial respiration is to be continued until he breathes of his own volition or his body stiffens in rigor mortis. The medical doctor when he arrives will encourage the men and no endeavour shall be made to move the man until he is breathing.

6. After he is breathing he will be transported to his home or hospital in a lying-down position, put to bed, and treated as for surgical shock.

REFERENCES

1. Goulstonian Lectures: Death by Electric Currents and by Lightning, **A. J. Jex-Blake.** *British Medical Journal* (London, England), March 1, 1913, pages 425–30; March 8, 1913, pages 492–8; March 15, 1913, pages 548–52; March 22, 1913, pages 601–3.

2. Elektrische Unfall (book), **Stefan Jellinek.** Franz Deuticke, Leipzig, Germany; Vienna, Austria, 1927.

3. Resuscitation from Shock, **Stefan Jellinek.** *Electrical Review* (London, England), January 5, 1940, pages 10–11.

4. Accidents Caused by Electricity (book), **Stefan Jellinek.** Vienna, Austria, 1924.

5. La Mort par les Courants Electriques, Courant Alternatif a bas Voltage, **J. L. Prevost, F. Battelli.** *Journal de Physiologie et de Pathologie Generale* (Paris, France), volume 1, 1899, page 399.

6. Courant Alternatif a Haute Tension, **J. L. Prevost, F. Battelli.** *Journal de Physiologie et de Pathologie Generale* (Paris, France), volume 1, 1899, page 427.

7. Courants Continues, **J. L. Prevost, F. Battelli.** *Journal de Physiologie et de Pathologie Generale* (Paris, France), volume 1, 1899, page 689.

8. La Mort par les Descharges Electriques, **J. L. Prevost, F. Battelli.** *Journal de Physiologie et de Pathologie Generale* (Paris, France), volume 1 1899, pages 1085, 1115.

9. Quelques Effets de Decharges Electriques, **J. L. Prevost, F. Battelli.** *Journal de Physiologie et de Pathologie Generale* (Paris, France), volume 2, 1900, page 40.

10. Influence du Numbre des Periodes sur les Effets Mortels des Courants Alternatifs, **J. L. Prevost, F. Battelli.** *Journal de Physiologie et de Pathologie Generale* (Paris, France), volume 2, 1900, page 755.

11. Electropathology, **R. H. Jaffé.** *Archives of Pathology,* American Medical Association (Chicago, Ill.), volume 5, May 1928, pages 837–70.

12. Investigation Made in Connection with the Preparation of Specifications for Rubber Gloves for Use on High Voltage Apparatus and Circuits, **The Electrical Testing Laboratories.** *Report 24610, Proceedings,* National Electric Light Association (New York, N. Y.), 1918, page 468.

13. Shock Threshold Fixes Appliances Insulation Resistance, **Gordon Thompson.** *Electrical World* (New York, N. Y.), volume 101, number 24, June 17, 1933, pages 793–5.

14. Electric Shock, **C.F. Dalziel, J. B. Lagen, J. L. Thurston.** AIEE *Transactions,* volume 60, 1941, page3 1073–8.

15. Current Passages Through the Human Body: **Electric Works, Kanton,** Zurich, Switzerland. *Bulletin,* l'Association Suisse des Electriciens (Zurich, Switzerland), July 7, 1929.

16. Experimental Electric Shock, **R. W. Ian Urquhart.** *The Journal of Industrial Hygiene* (Baltimore, Md.), volume 9, number 4, April 1927, pages 140–66.

17. Experimental Electric Shock II, **R. W. Ian Urquhart, E. C. Noble.** *The Journal of Industrial Hygiene* (Baltimore, Md.), volume 11, number 5, May 1929, pages 154–72.

18. Clinical and Neuropathological Aspects of Electrical Injuries, **Leo Alexander.** *The Journal of Industrial Hygiene and Toxicology* (Baltimore, Md.), volume 20, number 3, March 1938, pages 191–243.

19. The Reaction of the Rabbit to Electric Shocks, **G. E. Ettinger.** *Transactions,* Royal Society of Canada (Ottawa, Ontario, Canada), section 5, 1933, page 111–4.

20. The Reaction of the Rabbit to Electric Shocks Directed through the Heart, **G. H. Ettinger.** *The American Journal of Physiology* (Washington, D. C.), volume 105, number 2, August 1933, pages 457–68.

21. The Reaction of the Cat to Electrical Shocks Directed Through the Heart, **G. H. Ettinger.** *The American Journal of Physiology* (Washington, D. C.), volume 3, number 2, March 1935, pages 406–15.

22. The Effects of Electric Shock on the Heart, **G. H. Ettinger.** *Academy of Medicine* (Toronto, Ontario, Canada), March 13, 1934.

23. Effect of Electric Shock on the Heart, **H. B. Williams, L. P. Ferris, B. G. King, P. W. Spence.** *Electrical Engineering,* volume 55, number 5, May 1936, pages 498–515.

24. Physiological Studies in Experimental Drowning, **F. G. Banting, G. E. Hall, J. M. James, B. Leibel, D. W. Lougheed.** *Journal,* The Canadian Medical Association (Montreal, Quebec, Canada), volume 39, 1938, pages 226–8.

25. Electric Shock: Interpretation of Field Notes, **Wills Maclachlan.** *The Journal of Industrial Hygiene* (Baltimore, Md.), volume 12, number 8, October 1930, pages 291–9.

26. Electric Shock: Interpretation of Field Notes II, **Wills Maclachlan.** *The Journal of Industrial Hygiene* (Baltimore, Md.), volume 16, number 1, January, 1934, pages 52–64.

27. Five Years of Fatal Accidents in the Industry Point the Way to Prevention, **D. C. Stewart.** *Bulletin,* Edison Electric Institute (New York, N. Y.), August 1947.

28. Electrical Accidents and Their Causes: Ministry of Labour and National Services, Factory Department, London. *His Majesty's Stationery Office* (London, England), 1941–1948.

29. Review and Classification of Fatal Accidents in the Electric Light and Power Industry, **D. C. Stewart.** *Bulletin,* Edison Electric Institute (New York, N. Y.), 1943–1951.

30. Three Hunterian Lectures: The Mechanism Underlying Various Methods of Artificial Respiration, **Sir Arthur Keith.** *Lancet* (London, England), March 13, 1909, March 20, 1909, March 27, 1909.

31. Artificial Respiration in the Human Subject, **E. S. Schafer.** *Medico-Chirurgical Transactions* (London, England), volume 87, 1904, page 609.

32. The Relative Efficiency of Certain Methods, **E. S. Schafer.** *Proceedings,* Royal Society of Edinburgh (Edinburgh, Scotland), 1903.

33. Artificial Respiration in Its Physiological Aspects, **E. S. Schafer.** *Journal,* American Medical Association (Chicago, Ill.), volume 51, September 5, 1908.

34. Manual Artificial Respiration, **A. S. Gordon, F. Raymore, W. Sadore, A. C. Ivy.** *Journal,* American Medical Association (Chicago, Ill.), volume 144, number 17, December 23, 1950, pages 1,447–52.

35. Artificial Respiration, **A. S. Gordon, D. C. Fainer, A. C. Ivy.** *Journal,* American Medical Association (Chicago, Ill.), volume 144, number 17, December 23, 1950, pages 1455–64.

36. Breathing Machines and Their Use in Treatment; Report of the Respirators (Poliomyelitis) Committee, Medical Research Council, Privy Council (United Kingdom). *His Majesty's Stationery Office* (London, England), 1939.

37. Proceedings and Resolution of the Third Resuscitation Commission. *Science,* American Association for the Advancement of Science (New York, N. Y.), December 6, 1918.

Probability Method of Finding Reserve Capacity—Effect of Interconnections

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FELLOW AIEE

A further development in the author's method for finding the effects of interconnection on the service reliability of interconnected systems and for determining the optimum capacity of the interconnection is presented.

THE IMPORTANCE of the allocation of the reserve savings derived from interconnecting two systems does not need any emphasis. Yet this allocation, like most answers to problems dealing with questions of reserve capacity, has been and continues to be based, more or less, on rules of thumb. In another article,[1] the author presented a general method for calculating the effect of interconnecting two systems on their reserve requirements. That method, which is based on the probability theory, permits evaluating the effect of interconnections on the degree of service reliability of the interconnected systems. It is on this effect that the allocation of the reserve savings, derived from interconnections, should be based. This, in the author's opinion, is the rational approach to the problem.

In the previous article[1] and in other subsequent publications,[2] the author has introduced the concept of loss of load probability for measuring service reliability. In the general method just referred to, this is calculated on the basis of the actual daily maximum load duration curves of the interconnected systems. Calculations can be simplified if the actual daily maximum load duration curves[2] of the two interconnected systems are replaced by straight lines or portions of straight lines. In this article, the effect of interconnecting two systems on the degree of service reliability of each system is further investigated, assuming straight-line daily maximum load duration curves for both systems. In addition, the optimum interconnection capacity is determined on the same assumption.

ALLOCATION OF THE RESERVE SAVINGS

THE EXTENSIVE development of interconnections of electric power systems has been due to the advantages derived from them. On the economic plane these ad-

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Essentially full text of paper 51-198, "Determination of Reserve Capacity by the Probability Method—Effect of Interconnections," recommended by the AIEE Committee on Power Generation and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Toronto, Ontario, Canada, June 25–29, 1951. Scheduled for publication in AIEE *Transactions,* volume 70, 1951.

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vantages are (1) reduction in installed reserve, (2) reduction in spinning reserve, (3) economy loading, and (4) staggering of capacity installation.

The evaluation of the savings derived by each system from items 2 and 3 is straightforward and need not be considered here in detail. It consists in computing for each system the annual costs, under each item, with and without interconnection, the difference representing the annual savings.

The same general approach should be used in determining the "value" of the interconnection to each system from the standpoint of installed reserve capacity requirements. A and B are the two systems; L_{am} and L_{bm}, respectively, their maximum loads. The subscripts a and b are used to indicate quantities pertinent to system A and to system B, respectively.

Let P_{ea} and P_{eb} be the probabilities of loss of load of systems A and B without interconnection. P_{ea} and P_{eb} may or may not be equal, depending on the degree of service reliability desired in each of the systems in the interconnection.

Let it be assumed, now, that the two systems are interconnected with an interconnection of capacity R. Evidently, assuming no increase in the loads L_{am} and L_{bm}, the service reliabilities of both systems will increase, that is, P_{ea} and P_{eb} will decrease. Unless, however, the two systems are identical, in general the decrease or the probability of loss of load for the two systems will not be equal. The long range effect, assuming that P_{ea} and P_{eb} obtaining prior to the interconnection are satisfactory, is that the loads L_{am} and L_{bm} can be increased with no additions to the installed capacity of either system.

Starting with no interconnection and increasing the capacity R by small increments, these effects increase with the capacity R of the interconnection and a point of maximum return is reached beyond which any further increase of R will result in smaller and smaller incremental gains or even in no gains at all. From the reserve capacity standpoint there is thus a maximum practical limit for the capacity of the interconnection. It is conceivable for this value of R to be exceeded on considerations other than reserve capacity, such as may arise, for instance, in interconnecting two stations with local loads when one station is completely shut down during part of the day or of the year.

Thus, from the reserve standpoint, the following questions arise in interconnecting the two systems:

1. For any given value of R, assuming constant loads, L_{am} and L_{bm}, what is the increase of the degree of service reliability of each system; and what is the optimum value of R, the capacity of the interconnection?
2. For any given value of R, assuming constant loss of load probabilities, P_{ea} and P_{eb}, by what amounts can the two loads L_{am} and L_{bm} be increased without increasing the installed capacity of either of the two systems which are interconnected?

Once these questions have been answered, the determination of the value of the interconnection to each system, from the standpoint of installed reserve capacity, becomes relatively simple.

Under question 1, assuming that the loads remain constant, the probability of loss of load of system A decreases from P_{ea} to P_{ea}'. To attain the same decrease by installing additional capacity with no interconnection, system A should spend a sum S_a. This sum then represents the investment value of the interconnection to system A from the standpoint of reserve requirements.

The total value of the interconnection to system A will be obtained by evaluating, according to conventional engineering economics methods, the savings derived from the installed reserve requirements, as well as those derived from all other sources, such as reduction of spinning reserve, economy loading, and so forth. For system B the value of the interconnection, from the standpoint of installed reserve, and the total value, inclusive of the savings from all other sources, are determined in a similar manner. The total savings for each system, and the grand total for both systems, can be plotted against the capacity R of the interconnection and the optimum value of R thus determined.

If, on the other hand, both or one of the two maximum loads L_{am} and L_{bm} increase, the interconnection will permit staggering the installation of the necessary additional capacity and the savings derived therefrom must be taken into consideration. The installation of additional capacity will affect the value of the interconnection to each system, a fact that must be taken into consideration when the effect is appreciable. The determination of the value of the interconnection to each system requires a knowledge of their probabilities of loss of load with and without interconnection. The remainder of this article will be devoted to the methods which are used in the calculation of these probabilities.

LOSS OF LOAD WITH NO INTERCONNECTION

Referring to Figure 1, C_a is the total capacity of system A, L_{am} the maximum load, R_{ao} the peak time reserve, and K_aL_{am} the minimum load during the period under consideration, all in kilowatts. C_b, L_{bm}, R_{bo}, and K_bL_{bm} are the corresponding quantities which apply to system B.

In Figure 1 it is assumed that the peaks of the two systems are coincident, that is, there is no diversity between them. This assumption is made to simplify calculations. In the more general case, any diversity between the two systems is taken into consideration by drawing the daily maximum load curves of the two systems in their proper relative position with respect to one another.

The probability of loss of load of system A, with no interconnection (assuming a straight-line daily maximum load duration curve and a step outage probability curve), is given by

$$P_{ea}=\Sigma p_k t_k=\Sigma P_k \Delta_k$$

where the summations are extended to all capacity outages O_k in excess of reserve, and p_k is the probability of a capacity outage exactly equal to O_k in system A; P_k is the probability of a capacity outage in excess of O_k in system A; t_k is the time during which the load of system A exceeds $C_a - O_k$; and Δ_k is the time interval between two successive capacity outages O_{k+1}, O_k. The summations are extended to all possible outage values.

If, in addition to using a straight-line daily maximum load duration curve, it is assumed that the logarithm of the probability P_k of capacity outages in excess of O_k varies linearly with O_k for all values of $O_k > R_{ao}$, that is, if it is assumed that

$$P_k = A_a \epsilon^{-aO_k}$$

where A_a and a are constants, the probability of loss of load P_{ea} takes the form

$$P_{ea} = \frac{A_a \epsilon^{-aR_{ao}}}{2a(1-l_a)L_{am}}[1-\epsilon^{-2a(1-l_a)L_{am}}]$$

where l_a is the daily maximum load ratio of system A.

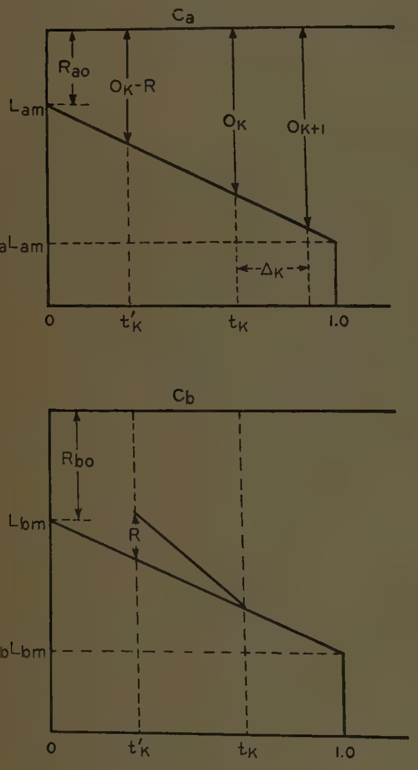

Figure 1. Assumed straight-line load duration curves for the two interconnected systems, A and B

Similar expressions may be written for system B by replacing the subscript a with the subscript b, as already noted.

LOSS OF LOAD WITH INTERCONNECTION

The probabilities of loss of load with interconnection can be calculated according to one of the following three methods:

1. The general method, using the actual daily maximum load duration curves in their proper relative positions. This method was developed in reference 1 and will not be discussed here.

2. The probability of loss of load of either system is calculated, assuming straight-line daily maximum load duration curves for both systems and no diversity between the two systems. The actual step curve of the probability of outages, in excess of the various capacity values of each system, is used in the calculations. This method will not be discussed here.

3. The probability of loss of load of either system is calculated assuming straight-line daily maximum load duration curves for both systems with no diversity, as under item 2. In addition, it is assumed that the probability of capacity outages in excess of O_k in system A is given by $P_k = A_a\ \epsilon^{-aO_k}$ and the probability of capacity outages in excess of O_b in system B is given by $P_b = A_b\ \epsilon^{-bO_b}$.

It can be shown that, with this method, the probability of loss of load P of system A is given by:

$$P_{ea} = \frac{A_a \epsilon^{-a(R_{ao}+R)}}{aL_1}[1-\epsilon^{-aL_1}] + \frac{C_2}{b(L_1+L_2)}\left[\frac{\epsilon^{(b-a)R}-1}{b-a} + \frac{\epsilon^{-B_1R}-1}{B_1}\right] + \frac{C_2}{b(L_1+L_2)B_1}\left\{\epsilon^{b\left(1+\frac{L_2}{L_1}\right)R}-1\right\}(1-\epsilon^{B_1L_1}) + \frac{C_2\epsilon^{-bL_2+b\left(1+\frac{L_2}{L_1}\right)R-aL_1}}{b(L_1+L_2)(b+B_1)}[1-\epsilon^{(b+B_1)R}] + \frac{C_2\epsilon^{-bL_2-aL_1}}{b(L_1+L_2)a}[\epsilon^{-aR}-1]$$

For brevity it has been put

$$L_1 = 2(1-l_a)L_{am}$$
$$L_2 = 2(1-l_b)L_{bm}$$
$$C_2 = aA\ _aA_b\ \epsilon^{-bR_{ao}}\ \epsilon^{-aR_{ao}}$$
$$B_1 = a + b\frac{L_2}{L_1}$$

In actual calculations some of the terms in this expression can be neglected.

MAXIMUM VALUE R_{ko}

Assuming straight-line load duration curves for both systems and no diversity, the value of R_{ko}, required by different values of capacity outages O_k in system A, is given by $O_k - R_{ao}$ for all outages O_k such that $R_{ao} < O_k \leq R_{ao} + R_{bo}$ and by

$$\frac{R_{bo} + \frac{(1-l_b)L_{bm}}{(1-l_a)L_{am}}(O_k - R_{ao})}{1 + \frac{(1-l_b)L_{bm}}{(1-l_a)L_{am}}} \quad \text{for all outages } O_k > R_{ao} + R_{bo}$$

These relations give the capacity R_{ko} of the interconnection required by any specific outages O_k. The value of R_{ko} increases with O_k. However, as previously noted, from a practical standpoint the capacity R of the interconnection need not be increased above the value for which any further increase would result in a negligible reduction of the probability of loss of load. In other words, in the determination of R only those outages O_k need be considered which have a relatively large probability p_k.

REFERENCES

1. Generating Reserve Capacity Determined by the Probability Method, G. Calabrese. AIEE *Transactions*, volume 66, 1947, pages 1439–50.

2. Determination of Reserve Capacity by the Probability Method—Simplified Methods—Indexes of Service Reliability, G. Calabrese. AIEE *Transactions*, volume 69, part II, 1950, pages 1681–88.

3. Outage Rates of Steam Turbines and Boilers, AIEE Committee Report. AIEE *Transactions*, volume 68, part I, 1949, pages 450–7.

Magnetization Current Inrush in Transformers

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ANALYTICAL solutions to nonlinear transients such as the phenomena of inrush currents in transformers are notoriously difficult to obtain unless a simple, convenient relationship exists between the dependent variables. Generally the transient may be determined by a graphical or step-by-step process. This procedure is lengthy and tedious and results only in a particular numerical solution which does not yield insight into the influence of changes of design or operating conditions. In light of these difficulties, it is desirable in this problem to make assumptions and approximations which will produce a simple convenient relationship between the variables, resulting in an analytical expression for the first crest and successive crests of the inrush magnetizing current.

In any analysis of inrush current, it generally is assumed that the transformer core follows the normal magnetization curve, neglecting the hysteresis and eddy loss in the core. Since these losses are small, such an assumption does not appreciably affect the results. Furthermore, it would be difficult to obtain the exact shape of the assymetrical hysteresis loops, even for use in a graphical solution.

The decay of the crest transient flux in the core from cycle to cycle depends upon the integral of the resistance drop for that cycle. In the early part of the transient the current is practically unidirectional and the accuracy of the calculated decay depends primarily on the accuracy of the assumed current near the crest value. It is therefore important that the approximating representation be accurate for values of the current near the crest. For smaller values of current errors in the assumed current do not appreciably affect the value of the integral or the decay and the representation may depart considerably from the actual value for smaller currents near the rated current of the transformer.

With this in mind, the normal magnetization curve of current versus flux linkages was fitted with an exponential function of the form

$$i = k_1 \epsilon^{k_2\phi}$$

which readily yields to analytical manipulation. This function offers an added advantage in that it is extremely simple to fit to the actual curve and the constants are obtained readily. If the actual curve is plotted on semilog co-ordinate paper, the fitting function is a straight line. Some judgment is required to find a suitable fit over an adequately wide range, but the choice is not too critical. The original magnetization curve to be fitted is seldom assigned with any high degree of accuracy in the region of high saturations, because of experimental difficulties. Thus any search for refinements in the fitting operation would be deemed unwise. In fact, the normal magnetization curve to be fitted may be obtained in the region of high flux density by the approximation

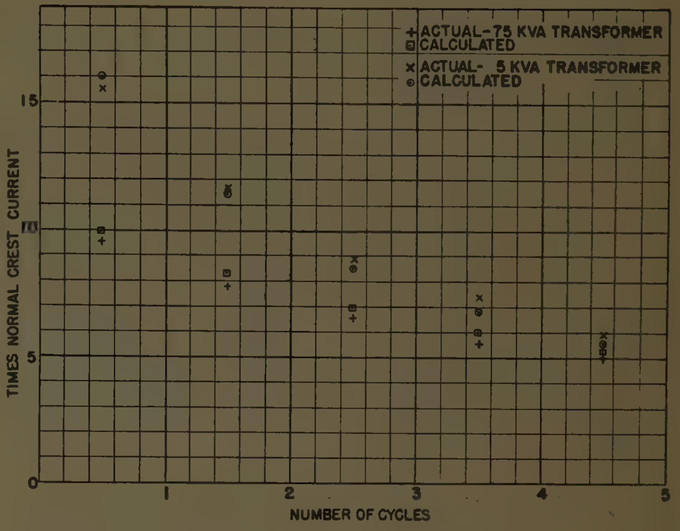

Figure 1. Calculated and measured inrush current crests

$$B = B_{\text{SAT}} + \frac{A_a + A_c}{A_c} H$$

where B is the equivalent flux density (gausses) defined as $\phi = NA_cB$, B_{SAT} is the saturating flux density (usually between 19,200 and 21,200 gausses), A_a is the space between the exciting winding and the core, A_c is the area of the core steel, and H is the magnetizing force.

By use of the exponential fitting function, the "nth" crest of the inrush current obtained is

$$i_n = \frac{k_1 \epsilon^a}{(2n-1)\dfrac{Rk_1k_2b}{\blacksquare} + \epsilon^{-(1+c)a}}$$

where

$$a = \frac{k_2E_M}{\blacksquare}$$

$$b = \frac{\pi}{2}\left[2 + \frac{a^2}{2!} + \frac{3}{4}\cdot\frac{a^4}{4!} + \frac{3}{4}\cdot\frac{5}{6}\cdot\frac{a^6}{6!} + \frac{3}{4}\cdot\frac{5}{6}\cdot\frac{7}{8}\,\frac{a^8}{8!} + \cdots\right]$$

c = per unit residual flux linkages

The complete article outlines procedures for determining intermediate values of current from which the rms value of the inrush current can be obtained. In the figure a comparison is shown between inrush current peaks obtained experimentally for the first 5 cycles and peak values calculated by means of the derived expression for a 5-kva and a 75-kva transformer.

Digest of paper 51-266, "The Inrush of Magnetizing Current in Single-Phase Transformers," recommended by the AIEE Committee on Transformers and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Toronto, Ontario, Canada, June 25–29, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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Frequency-Modulation Terminal Equipment for the Transcontinental Relay System

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To meet the exacting requirements of the new transcontinental microwave relay system, specially designed frequency-modulation terminal equipment was constructed. The terminal transmitter converts either message or television signals to a frequency-modulated signal centered on 70 megacycles and the terminal frequency-modulation receiver recovers these signals, thus providing a link between the relay system and other telephone facilities.

THE *TD-2* RADIO relay system provides a long-haul transmission facility for either television or multichannel message circuits. The radio transmitter of the *TD-2* system translates an input intermediate-frequency signal at 70 megacycles (mc) to the desired channel in the 3,700- to 4,200-mc range, while the radio receiver converts received microwave energy to the 70-mc intermediate frequency. Within the radio system, branching and switching for program and maintenance purposes are carried out at 70 mc.

The frequency-modulation terminal equipment provides means for applying the television or message signals to the radio system at 70 mc and for recovering the signals from 70 mc at receiving points. Message circuits are built up on a single-side-band suppressed-carrier frequency-division basis by the same equipment which is used for coaxial cable systems.[1] The terminal transmitter converts either of the two types of input signals to a frequency-modulated signal centered at 70 mc; the terminal receiver recovers the television signal or message complex from the 70-mc frequency-modulated intermediate-frequency signals. The frequency-modulation terminal equipment thus provides the connecting links between the *TD-2* radio system and other Bell System transmission facilities.

Since in the *TD-2* system the information is conveyed by frequency modulation, it is necessary to convert the entire message complex to the base frequency band before message groups or channels can be added to or extracted from a long through circuit. A long message circuit may include a large number of terminals in tandem; the requirements on linearity of a single terminal are therefore severe. An objective in the development of the terminal equipment was to meet long-haul systems requirements with as many as 16 pairs of terminals in tandem.

Figure 1 shows the frequency excursion of the intermediate-frequency portion of the system for the two types of signals. For message service the frequency deviation is centered about 70 mc, and since the components of the signal are symmetrical the average frequency is 70 mc. For television, the frequency excursion is unidirectional downwards from the tips of the synchronizing pulses which are held at 74 mc. In this case the average frequency may vary widely with the content of the television picture being transmitted.

FREQUENCY-MODULATION TRANSMITTER

THE TERMINAL transmitter is required to generate 70-mc frequency-modulated waves which deviate between the limits of 66 and 74 mc in accordance with the impressed television or multichannel telephone signals. A microwave heterodyne method of generating the 70-mc frequency-modulated signal was selected because it was found possible to design a highly linear deviator in the microwave region. This method also permits independent tests of the linearity of the transmitter and the receiver, thereby facilitating maintenance.

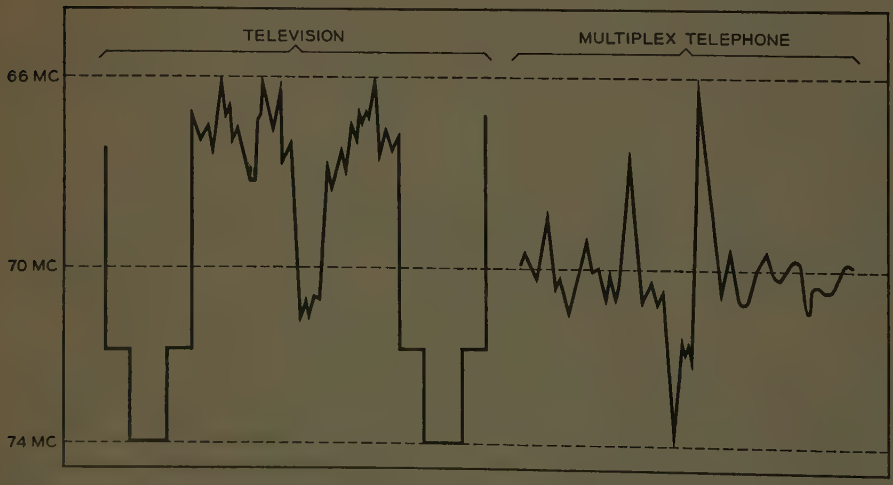

Figure 1. Normal frequency deviation for both television and multiplex telephone as used in the terminal equipment

Two reflex klystron oscillators are used; a 4,280-mc oscillator which is frequency-modulated, and a 4,210-

Second in a series of articles on the *TD-2* microwave radio relay system. See "A Broad-Band Transcontinental Radio Relay System," T. J. Grieser, A. C. Peterson (*EE, Sep'51, pp 810–5*).

Essential text of a conference paper, "FM Terminals for the *TD-2* Radio System," presented at the AIEE Summer General Meeting, Toronto, Ontario, Canada, June 25–29, 1951. Recommended by the AIEE Committee on Radio Communications Systems. **J. G. Chaffee** and **J. B. Maggio** are with the Bell Telephone Laboratories, New York, N. Y.

nc beating oscillator. The 4,280-nc oscillator is frequency-modulated oy superimposing a modulating signal on the repeller electrode bias voltage. Figure 2 shows the frequency and output of a typical ube as a function of repeller voltage. When the tube is operated into a matched load he rate of change of frequency with respect to changes in epeller voltage passes through a minimum near a point of maximum output. With a total deviation of 8 mc, the lifference in frequency-modulation sensitivity over the requency swing would be sufficient to produce intolerable nterchannel modulation in the transmission of multi-hannel telephone signals. However, the operating frequency of the reflex oscillator is subject to modification by he load impedance seen by the oscillator. This effect is ommonly called "pulling." In the case of the deviation oscillator, use is made of this effect to provide deviation inearity over a range of more than 10 mc. The load circuit for the 4,280-mc deviation oscillator consists of a ariable attenuator, a short length of waveguide, and a ariable-position short circuit. Adjustment of these two ariables allows complete control of the reactance seen at he output of the deviation oscillator. The length of path o the movable short circuit is so chosen as to provide the most favorable rate of change of reactance with frequency. At the optimum adjustment, the reactive component of the oad pulls the frequency of the oscillator by just the right amount necessary to straighten out the deviation characteristic. This effect is shown by the dotted curve of Figure 2.

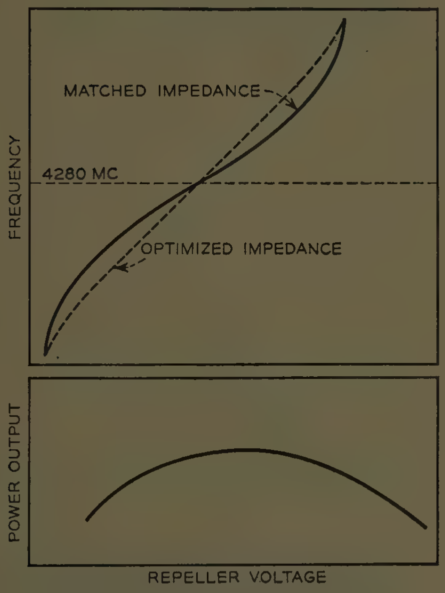

Figure 2. Typical characteristics of a reflex klystron

A functional diagram of the frequency-modulation transmitter is shown in Figure 3. A portion of the output of the leviation oscillator is fed through a directional coupler to he crystal mixer where, by combination with the output of he 4,210-mc fixed-frequency beating oscillator, a 70-mc ntermediate-frequency signal is produced. This signal arries a faithful reproduction of the frequency modulation which has been imparted to the deviation oscillator. A power of about 1 milliwatt is obtained at the output of the crystal mixer. This signal is amplified in a broad-band limiter-amplifier which removes the incidental amplitude modulation and then is applied to the radio transmitter either directly or through 70-mc switching circuits.

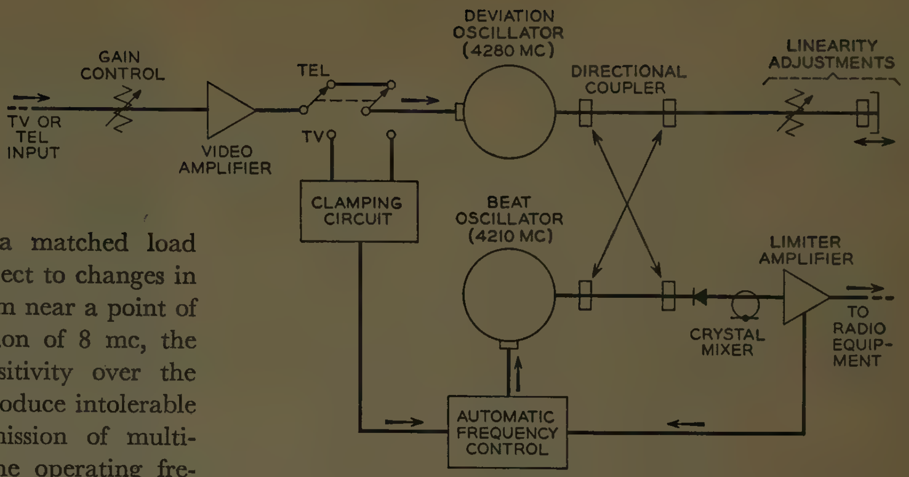

Figure 3. Block diagram of the frequency-modulation transmitter

The base-band input signal to the transmitter is applied through a variable attenuator to a feedback video amplifier having a voltage gain of 42 decibels. The output of this amplifier is impressed on the repeller electrode of the deviation oscillator klystron.

For television transmission, the voltage applied to the repeller of the deviation oscillator is "clamped" to a predetermined negative value during each synchronizing pulse by conventional circuits.[2] This process is, in effect, the insertion of a d-c component of proper magnitude to offset the dependence of the peak values of the synchronizing pulse upon the picture content of the signal, as would be the case if only the a-c components of the signal were transmitted. This amounts to the transmission of video signal components down to direct current. The frequency of the transmitter is restored to a fixed frequency (74 mc) during the peak of each synchronizing pulse. For message transmission, the clamping circuit is disabled.

The average frequency of the transmitter is stabilized by an automatic-frequency-control circuit. A portion of the 70-mc output is diverted, and after passing through a gated amplifier is applied to a discriminator circuit of conventional design. For television transmission, the amplifier is gated only during the synchronizing pulses, and the discriminator is adjusted to a crossover frequency of 74 mc. For message operation, the gated amplifier is operated continuously and the discriminator is adjusted to hold an average output frequency of 70 mc.

FREQUENCY-MODULATION RECEIVER

THE RECEIVER contains a broad-band 70-mc amplifier, a limiter, a discriminator-detector, and a balanced video amplifier, as shown in Figure 4. The 2-stage instantaneous amplitude limiter makes use of silicon varistors which are shunted across the relatively high impedance plate loads of the two tubes. The varistors are negatively biased, and

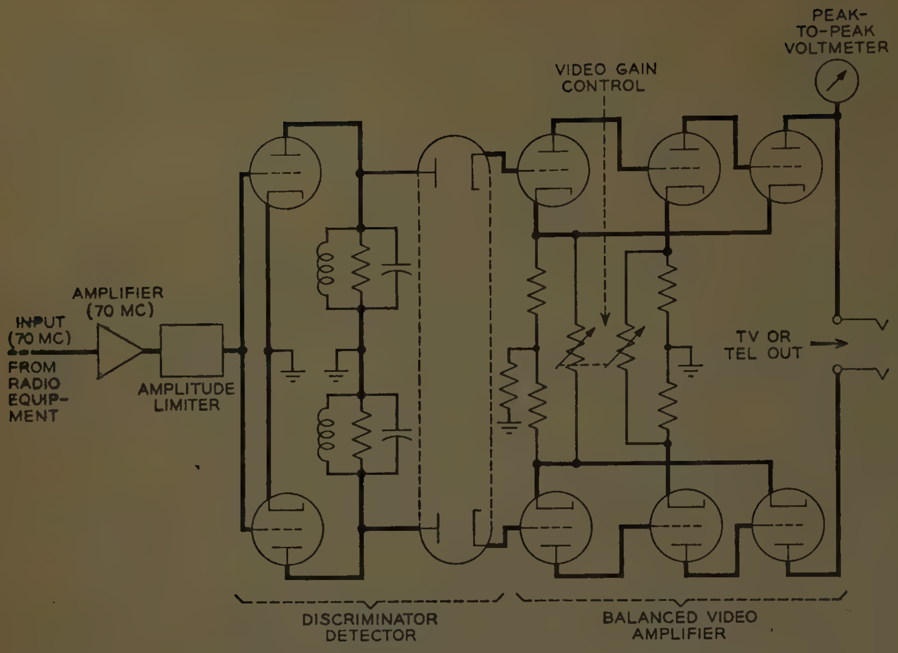

Figure 4. Schematic of the frequency-modulation receiver

until the bias potentials are overcome by the plate voltage variations produced by the 70-mc signals, they have very little effect upon the plate load impedances. The biases, however, are overcome during positive and negative peaks of the signal wave and the instantaneous gain of the stage is drastically reduced. The limiter output is roughly a square wave having an amplitude substantially independent of the level at the input of the receiver. In this way, small amplitude variations occasioned by noise or other effects are removed and the consequent noise improvement due to frequency modulation is realized.

The discriminator circuit follows early conventional practice. The signal at the output of the limiter is delivered to two tubes; each tube has as a plate load a simple antiresonant circuit. One circuit is tuned to about 56 mc while the other circuit is tuned to about 85 mc. The frequency-modulated signals produce corresponding amplitude variations in the voltages appearing across the two tuned circuits. These variations are detected by diode rectifiers which are connected to deliver a balanced video voltage of about 1.25 volts peak-to-peak. Controls are provided for adjusting the circuit elements of the discriminator circuits and for balancing the gains of the two vacuum tubes to produce a linear over-all characteristic.

Substantial negative feedback is provided in the balanced video amplifier to suppress longitudinal components, thus insuring that the output signal is well balanced. An amplifier gain control is provided and a peak-to-peak voltmeter is connected across one side of the balanced output circuit. This meter is used to monitor the transmission level for television transmission.

TERMINAL TEST EQUIPMENT

At terminal locations, a terminal test console is provided to measure the frequency deviation of the transmitter, the linearity of the transmitter or receiver, and for routine observation of waveforms at video frequencies. The console includes a continuous-wave signal generator covering the range from 50 to 90 mc, a broad-band oscilloscope, an electronic switch, and a frequency-modulation receiver, together with patching facilities and power supplies. A rather unique linearity test set also is included.

For deviation measurements, the intermediate-frequency signal being monitored is patched into one input of the electronic switch while the signal generator is connected to the other input. The electronic switch alternately samples the two input signals at a rapid rate and delivers the composite signal to the frequency-modulation receiver. After detection, the recovered video signal is displayed on the oscilloscope. The presentation consists of the video waveform with a superimposed straight line corresponding to the frequency of the continuous-wave signal generator.

This line traverses the video wave as the frequency of the signal generated is varied, and the instantaneous frequency at any portion of the video wave may be determined by matching the straight line to it and noting the signal-generator frequency. Figure 5 shows the oscilloscope presentation with the transmitter being modulated by a television test pattern. The output frequency of the oscillator was 69 mc.

For measurement of the linearity of the frequency-modulation receiver, the linearity test set is connected to a frequency-modulation transmitter which is arranged to drive the receiver under test. The linearity test set supplies a low-level 100-kc modulating voltage to the deviation oscillator and a high-level 60-cycle voltage to the beating oscillator of the transmitter. For this test the transmitter automatic-frequency-control circuit is disabled. Under these conditions the signal delivered to the receiver discriminator swings over approximately 8 mc at a 60-cycle rate and over a small range (less than 1 mc) at a 100-kc rate.

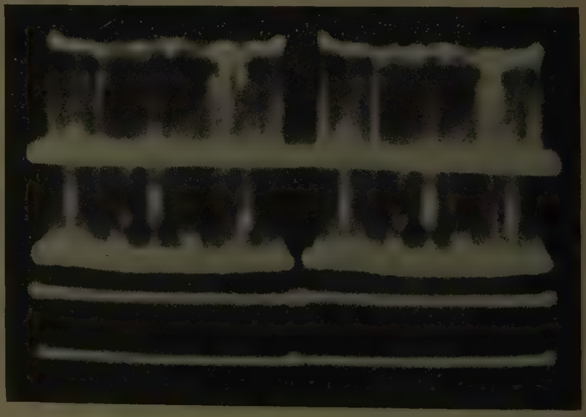

Figure 5. Oscilloscope display of the electronic switch detected output showing the 69-mc signal of the continuous-wave oscillator superimposed on television modulation

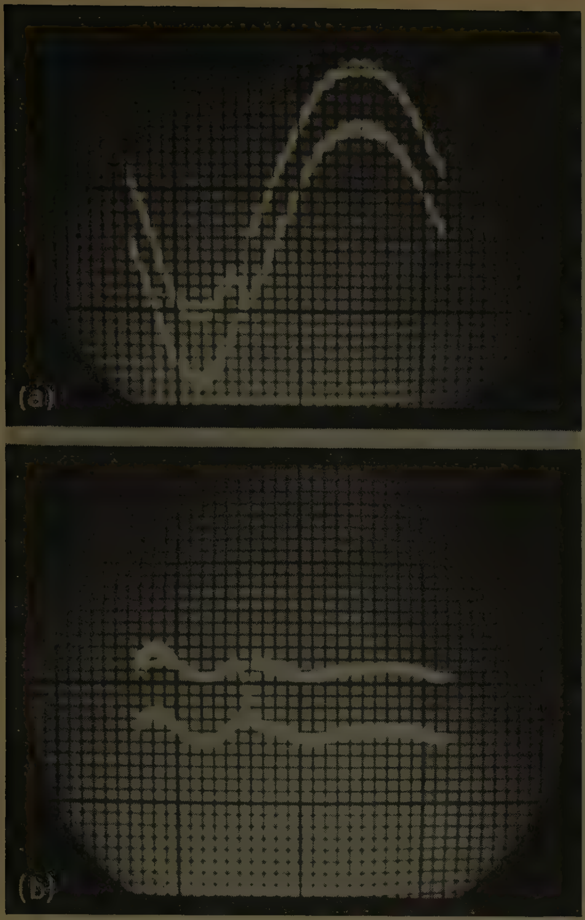

Figure 6. Oscilloscope display of transmitter nonlinearity: (a) after preliminary adjustment; (b) after complete adjustment. Scale is 1 per cent between traces

Since the 60-cycle and 100-kc modulations are produced by modulating separate klystron oscillators, the 100-kc component of the deviation is constant. The 100-kc component of the receiver output is then proportional to the slope of the discriminator characteristic and nonlinearity of the characteristic results in a 60-cycle envelope of the 100-kc signal. This envelope is recovered in the linearity test set. The a-c component is applied to the vertical input of the oscilloscope and the horizontal deflection is synchronized with the 60-cycle modulation. To provide a linearity scale, the amplitude of the 100-kc wave applied to the transmitter is changed by a known amount on alternate sweeps. With the sweep synchronized with the 60-cycle modulating voltage, the oscilloscope displays two traces which are separated by an amount dependent on the change in amplitude of the 100-kc signal on alternate sweeps. The separation between the traces corresponds to a definite amount of nonlinearity and the adjustment of the receiver may be determined quantitatively by comparing the departure of either trace from a straight line with the vertical distance between the two traces. The receiver controls are normally adjusted so that the maximum changes in linearity over an 8-mc range do not exceed 2 per cent.

For measurement of transmitter linearity, the same setup is made except that both the 100-kc small signal and the 60-cycle large signal are applied to the deviation oscillator of the transmitter under test. The time constant of the automatic-frequency-control circuit in the transmitter is modified so that it operates rapidly enough to follow the 60-cycle frequency modulation of the deviation oscillator, but not the 100-kc deviation. Because of this action the frequency of the beating oscillator follows the 60-cycle modulation of the deviation oscillator and the output of the transmitter does not contain the 60-cycle component of frequency modulation. The signal therefore utilizes only a narrow range of the receiver discriminator characteristic. On the other hand, since the 100-kc deviation takes place progressively over a 10-mc range of the deviation oscillator characteristic, any variation in deviation sensitivity (corresponding to departures from linearity) produces a 60-cycle envelope of the recovered 100-kc signal. This detected envelope is displayed on the oscilloscope. Figure 6 shows typical oscilloscope displays of transmitter nonlinearity. The upper part indicates a partial adjustment of the klystron load impedance, while the lower part shows the optimum obtained with a particular oscillator tube. The distance between the two traces represents 1-per cent nonlinearity of deviation.

While the transmitter is being so tested, the magnitude and phase adjustments of the deviation oscillator load impedance are varied as required to meet the desired linearity of deviation. This is normally held to within 1 per cent over the 10-mc range.

REFERENCES

1. Frequency Division Techniques for Coaxial Cable Networks, R. E. Crane, J. T. Dixon, G. H. Huber. AIEE *Transactions*, volume 66, 1947, pages 1451–9.

2. Clampers in Video Transmission, S. Doba, Jr., J. W. Rieke. AIEE *Transactions*, volume 69, part I, 1950, pages 477–87.

Beta-Ray Gauge Checks Uniformity

In the first installation of its kind, a General Electric beta-ray gauge is being used at the Antioch, Calif., plant of the Fibreboard Products Corporation to help maintain accurate and uniform weight of milk-carton paperboard. The gauge, mounted on one of the company's 136-inch paperboard machines, records the varying amounts of beta rays absorbed by the board as it passes through the gauge head of the noncontacting device. The amount of beta rays absorbed varies with the weight of the board, thus allowing a constant check to be maintained. Variations as slight as one per cent from the desired weight per unit area of the board are indicated and recorded automatically. Operators are able to make adjustments of the processing machinery as needed to produce paperboard of uniform weight. This is particularly important in the case of milk-carton board and similar material that is run through folding machines which operate on extremely close tolerances. The gauge, which is not affected by the speed, consistency, or temperature of the material being measured, also may be applied to other materials. Since no part of the gauge is in actual contact with the material being measured, it leaves no mark or scratch.

Operation of Bushings in Carbonized Oil

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CIRCUIT-BREAKER BUSHINGS, or load-ratio control-transformer-contactor bushings, may operate with one end immersed in oil containing various concentrations of small carbon particles. Such particles may be attracted to the bushing insulator surface. The behaviour of carbon particles in oil was investigated for the purpose of finding means of minimizing or avoiding the accumulation of carbon particles on the bushing insulator surface.

Oil carbonized by exposure to a low-current a-c arc was examined under a microscope. The particles floating in the oil were found to range in diameter from less than 0.1 micron to about 10 microns, most particles being under 0.5 micron. Myriads of particles tend to collect in lace-like patterns in which the individual particles are separated by small spaces. Chemical analysis disclosed that, in addition to carbon, the particles contain within or about themselves appreciable percentages of acids and solids representing various stages of decomposition of oil. It is probable that some of these materials form transparent high resistance envelopes surrounding a core which is largely carbon.

A small porcelain bushing in a glass tank of clean oil was energized at a-c operating voltage and a few drops of carbonized oil were placed in the clean oil near the porcelain. The particles gradually lined up, drawing a local flux plot and moving toward the porcelain. On reaching the porcelain the particles assumed a stable flux-line pattern partly suspended in the oil. More drops were inserted and the action was allowed to continue. Later when the bushing was removed from the oil there was found a localized carbon deposit similar in pattern to that observed on large bushings in service. At a higher voltage corresponding to high potential test value, turbulence appeared in the oil and the carbon began streaming from the bushings.

Investigation disclosed that the effective force on carbon particles results from spatial nonuniformity of the a-c field and tends to move the particles toward a region of greater field strength.

Mathematical evaluation of forces on particles disclosed that macroscopic nonuniformity of field produced by bushing design configuration causes a force on a particle which is negligible compared to gravity. Further mathematical investigation disclosed significant forces of the order of 110 times gravity resulting from regions of stress concentration caused by microscopic inclusions or bubbles in the bushing insulation surface. Another type of microscopic stress concentration producing significant forces of the order of 2,200 times gravity was found to result from proximity of a carbon particle in the oil to the location of an abrupt change in dielectric constant at the interface with the bushing insulation surface. These conclusions were confirmed by analysis of dielectric fields plotted from measurements on enlarged models immersed in a conducting bath in an electric field.

Typical carbon deposition phenomena may consist of four steps:

1. The particles are brought near the bushing insulator surface by oil circulation currents.
2. Stress concentrations resulting from conducting inclusions or bubbles in the insulator surface attract the particles to the surface.
3. Stress concentrations resulting from discontinuity of dielectric constant hold the particles firmly against the surface.
4. The presence of particles on the surface produces additional local stress concentrations, thus increasing the force available to attract additional particles.

Deposition caused by conducting inclusions or bubbles can be minimized by using a glaze which is homogeneous. Inhomogeneities which are likely to cause carbon deposition are detected sometimes by visual examination of transparent glazes. For transparent or opaque glazes they can be discovered by etching with hydrofluoric acid. Out of many samples tested, all glazes which showed homogeneity under hydrofluoric acid etching performed well in carbonized oil.

Deposition can be avoided by coating the insulator with a layer of homogeneous material matching the dielectric constant of oil (about 2.2). A number of suitable organic materials are available but no vitreous or ceramic material has been found. Theoretically the use of an insulator with a dielectric constant less than that of oil would result in particles being repelled from the insulator surface.

An alternative method of avoiding deposition is reduction of voltage gradient in the oil, particularly reduction of the component parallel to the insulator surface.

These conclusions were verified by accelerated laboratory tests on full size bushings. Two full-size bushings, usually of the 115-kv rating, were mounted in a large tank of oil and excited at normal voltage for eight hours. Carbon particles were formed continuously by the passage of a 60-cycle current of 0.22 ampere through an arc between two tungsten electrodes spaced 0.1 inch apart in the oil below the bushings. With new oil, several days of arcing were necessary to establish suitable conditions for testing. The severity of the test conditions is indicated by power factor readings up to 95 per cent on oil samples removed from the bottom of the tank. The use of these features on standard bushings has given improved performance.

Digest of paper 51-258, "Operation of Bushings in Carbonized Oil," recommended by the AIEE Committee on Switchgear and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Toronto, Ontario, Canada, June 25–29, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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Line Insulator Loss Under Normal Conditions

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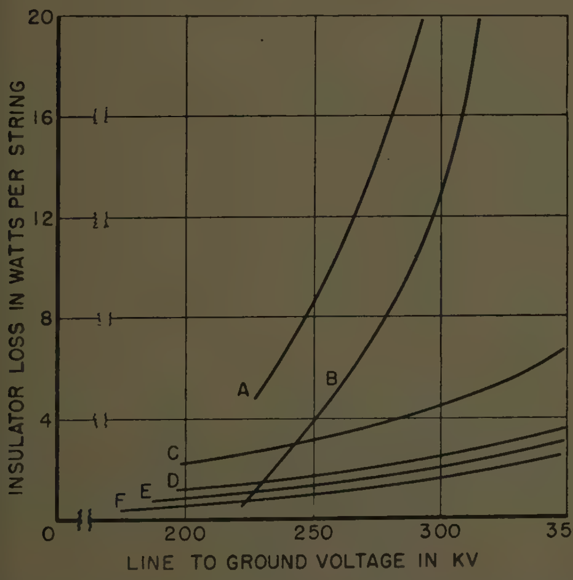
MOST OF THE INFORMATION in the literature on line insulator losses is concerned with conditions eading to flashover. Much less information is available n the loss characteristics of insulators under normal onditions, and that available is somewhat contradictory. summary of published information is presented in igure 1. Information on insulator loss under normal onditions is of considerable interest to corona loss investiators because it is desirable to be able to differentiate etween corona and insulator loss. Utility engineers requently are concerned about normal insulator loss vhen attempting to evaluate system losses.

The measurements described here were made on the 00-kv test project of the American Gas and Electric Company. Two methods were used. One method was o use the leakage current across the grounded insulator nit. In the other method a ground plane was contructed in such a manner that it collected substantially ll of the capacitive current which flowed to ground. A emotely controlled relay was used so that either current rom the ground end unit, or this current plus the current rom the ground plane, could be used to measure insulator oss. An extremely sensitive wattmeter was used which s one of the corona-loss meters designed especially for the Tidd 500-kv corona tests. Using the most sensitive scale n this meter, a deflection of 2 per cent of full scale was 0.5 watt.

Both graphic and loss versus voltage data were taken. During graphic recording, the losses on a 26-unit horizontal and a 34-unit vertical string were recorded alternately for periods of 20 minutes each.



igure 1. Loss on clean, dry insulator strings observed by ifferent investigators. A. Vertical, 24 units.[1] B. Horizontal.[1] C, D. Vertical, 26 units,[2] decreasing and increasing voltage. . Vertical, 26 units.[3] F. Vertical, 26 units.[4] Author's measrements indicate fair-weather loss is practically zero, and certainly less than two or three watts up to 289 kv

Fair-weather insulator loss was found to be apparently negligible, and definitely less than 2 or 3 watts even at 289 kv line-to-ground. Insulator loss is a function of both contamination on the surface and amount of moisture present. It appears to be more a function of weather than of voltage. Insulator loss versus humidity data taken at different voltages are shown in Figure 2.

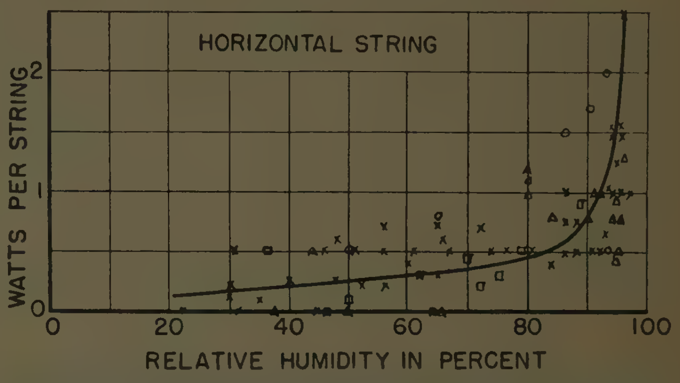


Figure 2. Insulator loss as a function of relative humidity. Δ 254 kv; × 222 kv; ○ 194 kv; □ 157 kv; all voltages line-to-ground

From graphic measurements, a 380-kv line can be expected to have a long-time average insulator loss of 30 to 45 watts per 3-phase mile, assuming 15 insulator strings per mile. This loss is negligible compared to normal I_2R loss. Horizontal insulator strings are washed on both sides, whereas a vertical string is washed only on the top side of the insulator units. For this reason, the loss on horizontal strings is generally less, being about 60 to 70 per cent.

REFERENCES

1. 500-Kv Experimental Station at Chevilly—Results of a Year's Tests on Use of Bundle Conductors, Corona Effects, Clearance, P. Ailleret, F. Cahen. *Paper Number 410*, International Conference on Large High-Voltage Electric Systems (Paris, France), 1948.

2. Electrical Characteristics of Suspension-Insulator Units, C. L. Dawes, R. Reiter. AIEE *Transactions*, volume 56, 1937, pages 59–66.

3. Comparative Investigations of D-C and A-C Corona on Two-Conductor Transmission Lines, R. Strigel. Wissenschaftliche Veroeffentlichungen aus den Siemens-Werken (Berlin, Germany), volume 15, part II, 1936, pages 68–91.

4. Methods of Controlling Radio Interference, C. V. Aggers. AIEE *Transactions*, volume 59, 1940, pages 193–201.

Digest of paper 51-224, "Line Insulator Loss Under Normal Conditions—500-Kv Test Project of the American Gas and Electric Company," recommended by the AIEE Committee on Transmission and Distribution and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Toronto, Ontario, Canada, June 25–29, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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Verifying Circuit-Breaker Interrupting Capacity

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TWELVE high-speed 230-kv oil circuit breakers rated 10,000,000 kva interrupting capacity are installed now in transmission-line and bus-tie positions of the left switchyard at the Grand Coulee Power Plant. The development of these important pieces of protective equipment has required extensive short-circuit testing both in a manufacturer's high-power laboratory and at Grand Coulee Dam. This article covers the final stages of that development and describes in particular the field tests which were made in August 1950 in order to verify the circuit-breaker interrupting capacity rating of 10,000,000 kva and also to determine any possible margin above this figure.

The last three of the total of 18 giant 108,000-kva water wheel generators will be installed at Grand Coulee before the end of 1951. On the 230-kv solid ring bus[1] receiving power from the generators, after additional transmission lines are completed, a 3-phase asymmetrical fault approaching 15,000,000 kva eventually may be possible. However, with overhead ground wire protection at the switching station and for one mile out on the lines, bus faults are considered extremely unlikely, and at one mile the maximum asymmetrical fault would not exceed 12,000,000 kva.

Figure 1. Two tank type 230-kv 10,000,000-kva 3-cycle circuit breakers in the special test bay at Grand Coulee Power Plant illuminated by an arcing fault test at night

The design features of the tank-type 230-kv 10,000,000-kva 3-cycle circuit breaker tested at Grand Coulee Dam have been described previously before the Institute.[2] The dead-tank construction not only provides inherent mechanical strength but also is adapted for the use of conventional through-type current transformers surrounding the lead-in bushings. Highly effective multiflow interrupter assemblies, only one per terminal, interrupt fault currents in less than 3 cycles on both normal tripping or on rapid reclosing duty with reclosing intervals of 20 cycles or even less.

Supplementary spring-driven pistons provide oil flow in the low-current range associated with the opening of transmission-line charging currents which are cleared with almost complete absence of delayed arc restrikes.

The first group of field tests consisted of 16 operations, dropping 100 and 300 miles of 230-kv transmission line. The satisfactory interrupting performance demonstrated the ability of the test circuit breakers to handle this type of service without appreciable overvoltages.

The 13 single-phase short-circuit tests covered a range of fault duty from 490,000 kv to 10,650,000 kva, on an equivalent 3-phase basis. Also a rapid-reclosing test interrupting approximately 8,000,000 kva was completed successfully with a reclosing interval of only 18.4 cycles.

Figure 1 shows the two test circuit breakers in the special test bay during one of the arcing fault interrupting tests at night.

High-power laboratory interrupting tests, made both before and after the field tests, included still higher fault currents at reduced test voltage to determine what effect variations in timing the parting of contacts with respect to the current wave would have on the severity of circuit-breaker duty. The most severe tests were found to be those asymmetrical fault current tests which included in the arcing period part or all of a small half-cycle of current followed by a large half-cycle of current before final arc extinction. The highest power field test was of this maximum severity type, as were laboratory tests which were carried up to currents equivalent to nearly 12,000,000 kva.

On the basis of both laboratory tests and the field tests at Grand Coulee Dam, it has been determined that the dead-tank circuit breakers now installed in the 230-kv Coulee switchyard are capable of interrupting short-circuit power up to at least 12,000,000 kva on normal operating duty.

Digest of paper 51-257, "Interrupting Capacity Verification of 10,000,000-Kva 230-Kv Oil Circuit Breakers for Grand Coulee Power Plant," recommended by the AIEE Committee on Switchgear and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Toronto, Ontario, Canada, June 25–29, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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REFERENCES

1. Development of the New 230-Kv Ring Bus for Grand Coulee Power Plant, N. G Holmdahl, C. L. Killgore. AIEE *Transactions*, volume 67, part II, 1948, pages 1369–81

2. High Voltage Oil Circuit Breakers for 5,000 to 10,000 Kva Interrupting Capacity W. M. Leeds, R. E. Friedrich. AIEE *Transactions*, volume 69, part I, 1950, page 70–78.

Modern Trends in the Design of Vertical Water Wheel Generators

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Progress in water wheel generator design is marked by improved reliability, greater compactness, and easier maintenance. Both umbrella-type and enclosed generators are still widely used, while underground and outdoor stations are becoming increasingly popular. Some design and construction problems of these generators are discussed.

HYDROELECTRIC power developments are long-term investments which require equipment of the highest reliability to insure long life, uninterrupted operation, and low maintenance cost. This requires machines made of the best available materials procured and fabricated with quality control. Windings must be maintained with a very high standard of cleanliness, and the vital parts such as the core, windings, rotor, and the bearings must be very accessible and arranged for easy inspection and maintenance.

Hydroelectric developments require very large capital investments. This results in a need to provide a design which will reduce the size and cost of the power station to a minimum. In the past 20 years much progress has been made in this direction, and the quality of the equipment also has been improved materially.

COMPACTNESS AND EASY MAINTENANCE

MODERN HYDROELECTRIC units in North America are chiefly low- or medium-speed machines of large capacity, weight, and size. Foreign installations are usually medium- and high-speed units. The large dimensions and weight of these units and of their component parts necessitate large power stations with high capacity cranes for the initial installation and maintenance.

The rotor and shaft assembly is usually the heaviest part and determines the size of the crane. The length of either the generator or water wheel shaft determines the elevation of the crane and crane ways. The design of the rotor is therefore a very important factor in determining the cost of the power station.

Two general types of bearing arrangements are in current use. In the first, the construction is arranged with a thrust and guide bearing above the rotor and various possible combinations of guide bearings below the rotor. This type is especially applicable to high-speed high-head units where the thrust is low, such as multiple-jet impulse and some Francis type turbines, but may be applied to any speed and size unit. The second and most successful arrangement for providing minimum weight and size is the umbrella-type design illustrated in Figure 1. This is the simplest construction from the standpoint of number of guide bearings, lubrication, and oil cooling. Since the rotor can be removed without disturbing the bearings and alignment of the shaft, it adapts itself to the lowest station heights and simplest maintenance operation. The shaft and bearings can also be installed and the shaft aligned while the rotor and stator are assembled separately, thus reducing the erection time and expense to a minimum. The usual reduction in the powerhouse height permitted by the umbrella unit is between 4 and 18 feet when compared to the equivalent 2-bearing machine.

An upper guide bearing is sometimes applied to the umbrella-type unit in cases where the machine proportions or bearing design do not provide sufficient machine rotor stability. In a few instances, customers have specified the upper bearing from a preference standpoint. In cases where the thrust bearing is not of the rigidly supported shoe type and thus does not provide stability of the rotor, the upper guide bearing is necessary.

Rotor. In recent years somewhat higher runaway speed has become permissible than formerly, due to the availability of higher strength sheet steel for the rotor rim. All modern large water wheel generators are made now with a rotor having a laminated rim. Due to shipping limitations, the rim is built in the field on a heavy cast steel or fabricated spider.

It is the practice of the Westinghouse Electric Corpora-

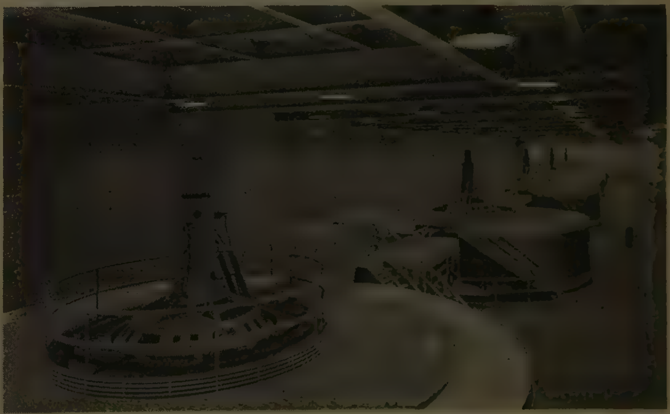


Figure 1. Typical large umbrella-type installation

Essentially full text of paper 51-216, "Modern Trends in the Design of Vertical Water Wheel Generators," recommended by the AIEE Committee on Power Generation and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Toronto, Ontario, Canada, June 25–29, 1951. Not scheduled for publication AIEE *Transactions.*

C. M. Laffoon, E. C. Whitney, and R. A. Baudry are all with the Westinghouse Electric Corporation, East Pittsburgh, Pa.

tion to shrink the rim on the spider to maintain the rim tight against the spider at normal speed. This prevents any relative motion between the rim and the spider, and avoids undesirable wear.

The laminated rim is made of precision-punched high-strength sheet steel punchings which are stacked on close-fitting pins and stud bolts. Dovetail slots are provided at its periphery to receive the poles. This practice requires a minimum of fitting in the field, resulting in a structure which can be assembled in the minimum time, and is the safest construction which can be built because every part of it is inspected and tested before it is assembled.

The rotor is bolted to and centered on the shaft flange which supports the thrust-bearing runner. The torque is transmitted either by a large key or by a number of dowel pins.

The simple and positive method of fastening the rotor to the shaft makes it possible to remove the rotor easily and quickly for inspection and maintenance work on either the rotor or the stator, without disturbing the bearing or shaft and its alignment.

Stator. The stator core is built in a frame which is now universally made of structural steel, and it is made in several sections to be within shipping space limitations. The insulated laminations are held between heavy end plates. The end plates and structural frame member are proportioned to limit the thermal stresses in the core to a minimum and to prevent a resonant condition with the pulsating magnetic forces. The stator frame is supported on seating plates and is held in position by radial dowel bolts. The dowel bolts are of sufficient strength and size to withstand the forces produced by any possible short-circuit torque. The sections of the core are held together by bolts which maintain high pressure at the face of the core split under all operating conditions. Provision is made for easy access to these splits to permit inspection and maintenance. Shims are provided to facilitate the retightening of the joint whenever found necessary. Should the split be allowed to become loose, vibrations and damage to the core and windings might occur. However, a well-maintained core split should last a relatively long time.

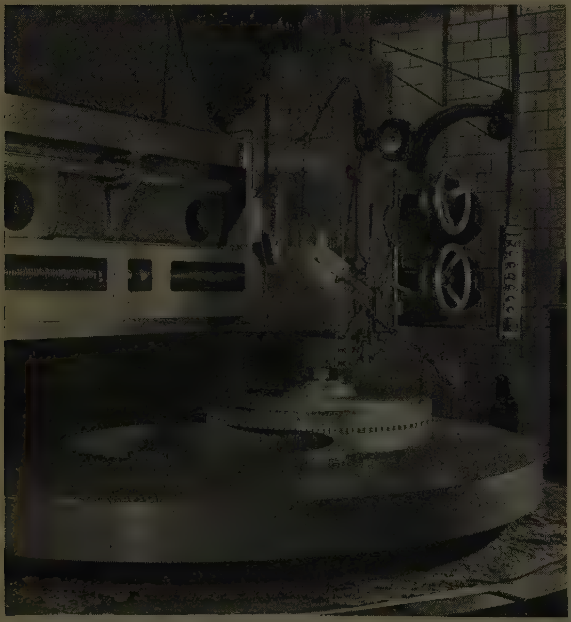


Figure 2. Precision boring mill enclosed in an air-conditioned room

Ventilation. During the last three years, approximately 92 per cent of units purchased above 3,000 kva have been provided with a recirculating air ventilating system with air-to-water coolers to dissipate the losses. This compares with 65 per cent between 1937 and 1940. The increased life and reduced maintenance with an enclosed air system justifies the additional initial investment, especially in locations where the available air is contaminated with dirt, dust, undesirable vapors or gases, and even insects. In addition, ventilation noises are reduced, fire protection is more easily applied, and the station is more comfortable to the operating personnel.

While most machines today are designed for indoor service, the outdoor or semioutdoor unit is gaining in popularity. For units of this type, the entire machine and housing may be above the deck at the back of the dam or the machine may be inserted in a well in the dam with an outdoor cover over the well. The unit then can be serviced by an outdoor crane. With the outdoor unit, more attention must be given to permit draining water under freezing conditions during prolonged shutdown and preventing condensation in the machine active parts. This is usually accomplished by installation of space heaters near the winding and core parts.

Underground applications are gaining favor in stations in Europe and South America. There are several under consideration in the United States and Canada at present. In these cases, dismantling height is of extreme importance in the cost of the station. Various housing modifications may be made to suit particular conditions. When carbon dioxide is used for fire protection, as is now the case for most large machines, special attention must be given to protecting station personnel in case of fire.

Excitation and Voltage Control. The excitation control of a water wheel generator must differ fundamentally from those of other classes of generators due to the high overspeeds which may be experienced in service. A water wheel generator will usually overspeed to between 130 and 150 per cent of normal speed on a full load rejection. In cases of full overspeed, the machines reach 180 to 300 per cent of normal speed, depending on the type of water wheel. This means that a regulator or other device must reduce the excitation to practically zero to prevent serious overvoltages occurring in the stator winding at overspeed. The residual voltage on the main exciter, unless eliminated by a differential field, may produce voltages in excess of rated a-c generator voltage above 230 per cent speed.

Although the use of minimum excitation devices to prevent pull-out or excitation reversal on steam turbine generators has been increasing and serves a useful purpose, the application of such a device to a water wheel generator must be treated with caution due to the high overspeed. The minimum excitation device should change the minimum excitation as a function of the generator electric power utput. The minimum excitation setting must be zero generator field current with less than 15 per cent power utput. The application then will permit the regulator o reduce the excitation to prevent serious overvoltages due to overspeed or line charging conditions. Normally water wheel generators can carry about 15 to 20 per cent normal power over a transmission line with zero excitation due to saliency without loss of synchronism. This, of ourse, varies with the transmission-line characteristics and requires a larger range of conditions on a minimum xcitation device. It is not desirable to have the minimum xcitation adjusted as a function of the turbine gate position because the gates are not necessarily in a closed position when zero excitation is required. Types of minimum xcitation devices which either set a minimum value of ield current or a rheostat arm position generally cannot be atisfactory without other relay protection requiring the opening field circuit breakers on overspeed. Since a arge majority of water wheel generators have the field connected directly to the exciter armature without a generator field circuit breaker, the use of such a circuit breaker involves extra equipment and space not normally equired.

The Rototrol type of pilot exciters with the associated tatic voltage regulators, used with considerable success on steam turbine generators and synchronous condensers, s not so readily applicable to water wheel generators. The overspeed condition again imposes problems not ncountered in other types of apparatus. It is difficult o design a static network for this type of regulator which is nsensitive to a wide range of frequency. The network ends to regulate voltage as a function of speed or frequency f compensating devices are not provided. Frequency ompensation should be provided to hold the steady-state egulated voltage to about ±10 per cent rated voltage at 0 per cent overspeed even with the rotating amplifier detuned due to the increased speed.

Basically, this method of regulation involves a self-xcited main exciter with a rotating amplifier bucking or boosting the excitation of the main exciter as required to egulate the a-c generator voltage. To accomplish good esponse, the rotary amplifier pilot exciter is normally part f a high-speed motor-generator set. In a water wheel tation, the power supply for the motor-generator set is ften from the generator being regulated rather than from constant frequency source. Consequently, the motor-enerator set in this case is subject to overspeed whenever he generator overspeeds. It is the feeling of the authors hat the motor-generator set should be capable of an overpeed of 50 per cent and be equipped with an overspeed evice which will trip it off the line at 50 per cent overpeed as well as trip other devices to protect the generator. ince 50 per cent overspeed is normal with full load reection, it is felt that the motor-generator set should be operating during this overspeed to control voltage. If he motor-generator set is tripped at a speed below 50 er cent overspeed, it is also necessary to trip the main exciter self-excited field to prevent this field forcing the main exciter voltage to a maximum with consequent dangerous a-c voltages during this overspeed. Other a-c generator overvoltage devices must also be used to protect against other types of failure such as loss of the motor-generator set, failure of overspeed devices, and overspeed during operation under hand control instead of regulator control.

Thrust Bearings. The highest reliability is expected from water wheel generator thrust bearings. For the largest units, the thrust bearings are required to support huge rotors and hydraulic thrust forces—sometimes larger than 1,000 tons—with low loss and negligible wear; and they are required to start and stop frequently. The first pivoted pad thrust bearings installed nearly 40 years ago are still performing satisfactorily in their original condition. Wear in itself is no longer considered a life limitation of a bearing.

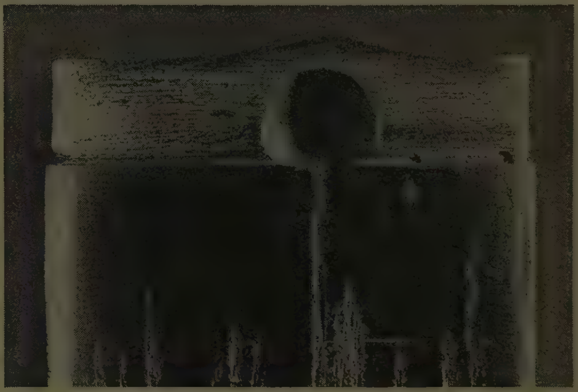


Figure 3. Laboratory-produced blister and pressure cavity on babbitted steel plate

To produce this kind of performance, particularly with the continuous increase in size of hydroelectric units which now require thrust bearings approaching 10 feet in diameter, the best materials with the best workmanship and extreme accuracy are required. These requirements have been established by experience and by many laboratory and field tests.[1]

Formerly thrust-bearing runners were made of chilled cast iron. Now they are made of clean electric alloy steel which makes it feasible to obtain smooth and hard bearing surfaces practically free of minor inclusions and other defects.

Precision type machine tools installed in air-conditioned rooms, where the air is maintained at a constant temperature and is free of dust, are used in final machining and finishing operations (Figure 2). This makes it possible to manufacture bearing surfaces of the required smoothness and accuracy under strict quality control.

The thrust-bearing pads are made of steel plate or forgings thoroughly heat-treated and annealed to remove internal strains and occluded gases. The bearing surfaces of these pads are covered with a tin base babbitt having suitable physical properties. However, in recent years

Figure 4. Fluorescent oil inspection of babbitt surface of pads to detect flaws

new types of babbitts having properties comparable to those of high tin base babbitts have been developed. A thrust bearing of a machine installed in 1943 with such a lead base babbitt has been operating very satisfactorily. This experience shows that similar babbitts could be used more extensively with no expected sacrifice in performance or reliability.

It has been known for many years that relatively large amounts of gases may be occluded in some types of steel. When present, these gases can develop very high local pressures and blisters may be formed in the babbitt of some very large thrust-bearing pads. Similar blisters, like one shown in Figure 3, have been reproduced in the laboratory and suitable heat-treating and annealing procedures were developed to remove the occluded gases before applying the babbitt. In addition to the removal of the occluded gases, it is also necessary to ascertain that the bond between the babbitt and the pad is entirely sound. This is done by means of the supersonic reflectoscope which is sufficiently sensitive to detect very minute cracks or discontinuities inside the babbitt metal parts. The fluorescent light inspection of the surface of the babbitt also will detect and locate very minute cracks (Figure 4). These modern methods of manufacturing and inspection of thrust bearings insure that only pads of the highest quality workmanship and material are used.

For satisfactory performance of the thrust bearing, the method of supporting the pads and the runner is equal in importance to the high quality of the bearing surfaces. The oil film thickness in a large thrust bearing is of the order of 0.001 to 0.002 inch, depending on size, load, and speed conditions. The thrust load on the thrust bearing varies between wide limits between no load and full load, particularly with adjustable blade type of water wheel runners. It is therefore necessary to have the bearing pads supported in such a way that equal load distribution will be maintained over all the pads under all operating conditions. This can be best obtained by using a symmetrical supporting bracket of the star type provided with a very rigid and substantial hub.

The surfaces of the thrust-bearing runner and supporting block are machined to a high degree of accuracy. However, any remaining waviness of small magnitude may be sufficient to cause appreciable load pulsations on the individual pads. These pulsations are kept to negligible values by providing sufficient flexibility between the pad and the supporting structure.

A modern combination of guide and thrust bearing for an umbrella-type generator is shown in Figure 5. The flexibility under each thrust bearing pad is provided in a high-strength steel support tube. The deflection of the steel tube can be measured by means of a dial indicator, thus offering a convenient means of checking the loads on the different pads when installing or realigning the machine.

Self-equalizing thrust bearings (Figure 6) have been used on some machines in which a combination of lever supports automatically equalizes the load on the individual pads. A Westinghouse-built bearing of this type installed for experimental purposes has been operating satisfactorily for approximately 20 years on a large high-speed generator.

Equalized types of thrust bearings also are considered beneficial in that they maintain a uniform load on all bearing pads should large misalignment of the machine be caused by foundation settlement or concrete growth. However, on most machines the length of the shaft is such that its flexibility is sufficient to prevent an appreciable overloading of any pads, even with an appreciable misalignment. In umbrella-type generators, the jack screw-supported thrust bearing provides a very important stabilizing effect for the rotor. With this type of machine, the self-equalizing type of bearing would not provide this necessary stabilizing effect, and in many cases would necessitate the use of an additional guide bearing above the rotor or the use of a larger and more rigid shaft.

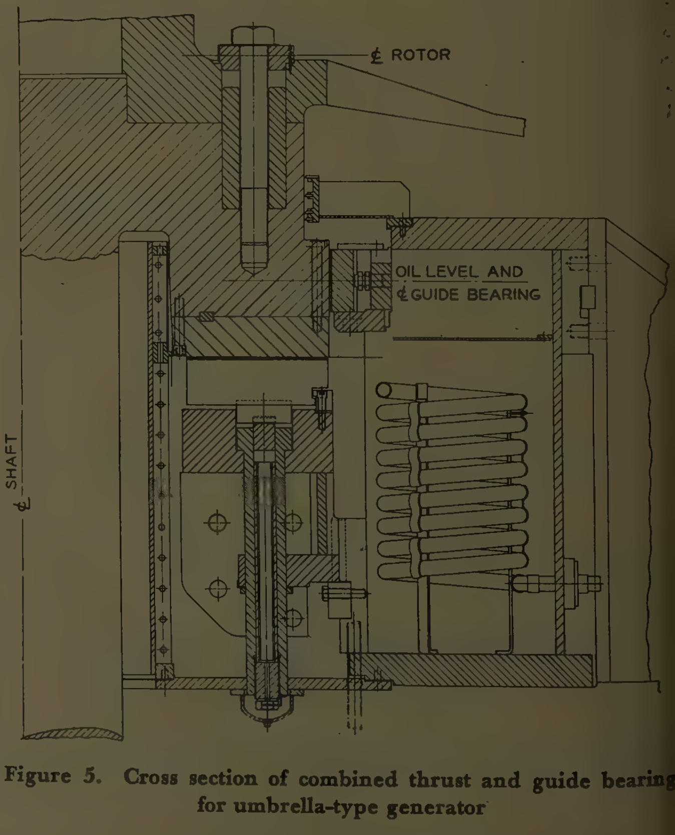
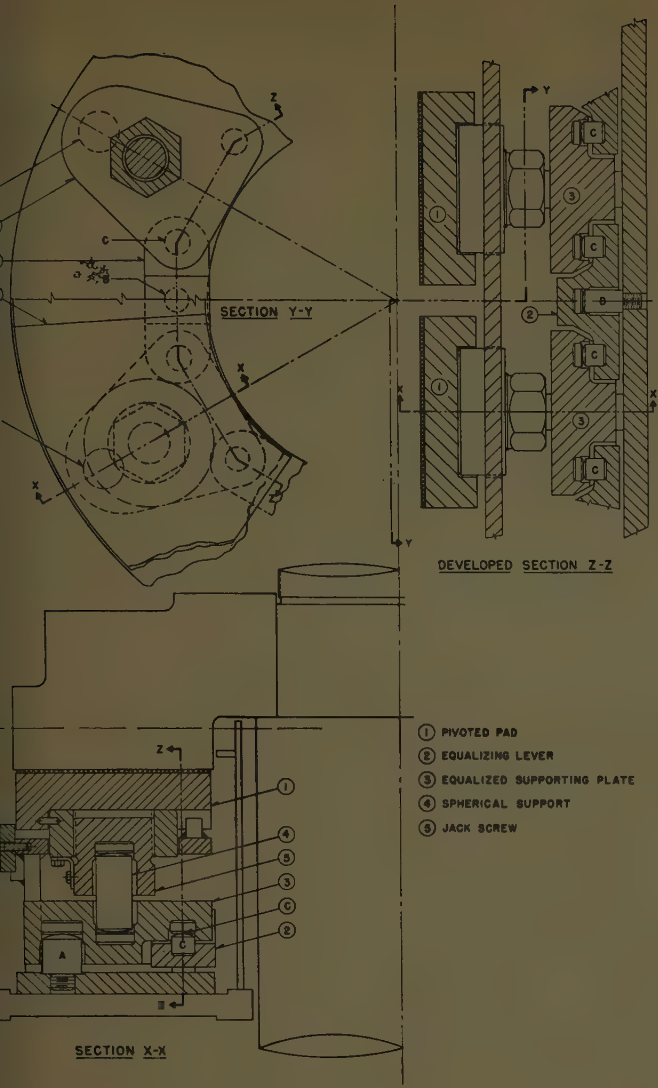


Figure 5. Cross section of combined thrust and guide bearing for umbrella-type generator



igure 6. Self-equalizing thrust bearing. The thrust load is arried by pivots A and B fastened to the bearing base. Pivoted ad 1 is carried by spherical support 4 which is supported by qualizing supporting plate 3. Equalized supporting plate 3 is ipported by pivot A and pivot C carried by equalized lever 2. ever 2 equalizes the reaction on all the pivoted pads, and jack screw 5 is for setting the pads at the required elevation

Experience has shown that a thrust bearing can be arted and stopped many times without any ill effect. Iowever, on machines used for peak load operation, very equent starts and stops are necessary. During these arts, there is a metal-to-metal contact and some resulting ear. To eliminate this condition and further increase ne reliability of the machine, some users prefer the use of me method of establishing in oil film previous to start. This can and is being done by using oil pressure lift at the enter of the pad, or by providing equipment to lift and wer the rotor automatically previous to start. Both ethods have their particular advantages and are equally ffective in producing frictionless starting.

On account of the high degree of polish and accuracy of achining of thrust bearing runner parts, it is essential that rovision be made for easy and adequate handling of the eavy runner and pads to prevent damage or accidents uring installation or maintenance. In a modern design, the complete thrust bearing of an umbrella-type generator can be installed or quickly lowered below the lower bracket by means of a motor operated mechanism which is provided as a normal part of the erection and maintenance equipment. Figure 7 shows such an installation. Large bearings with runners weighing as much as 12,000 pounds and individual thrust pads weighing 1,000 pounds can be removed from the pit by means of a special carriage and tracks.

Guide Bearings. Modern machines are now supplied with self-lubricating guide bearings, except on high-speed machines where the friction losses are too high and require flood lubrication.

This self-lubricating bearing running in an oil bath is of the pivoted pad type similar to the pivoted pad thrust bearing. It has much higher carrying capacity than the old sleeve type bearing; can be adjusted very easily, is self-aligning, and is not sensitive to self-induced vibrations.[2]

On umbrella-type generators, the large shaft flange on which the rotor is fastened is forged integrally with the shaft. It serves as a support for the thrust bearing runner and the periphery of the flange is used as a guide bearing journal. The complete assembly is very compact and thus reduces the problem of shaft alignment and installation to a minimum.

The elimination of the circulating oil system has facilitated the design of adequate seals which eliminate entirely oil leakage or vapors.[3]

WATER WHEEL GENERATOR WINDINGS

THE PRIMARY developments in high-voltage insulation for water wheel generator stators made since the introduction of the continuously taped asphalt-impreg-

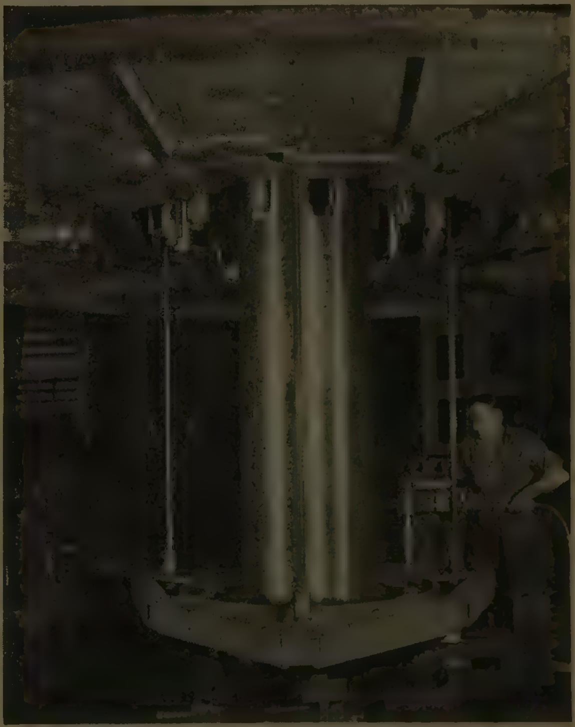


Figure 7. A thrust bearing lowering device with air motor for umbrella-type generator

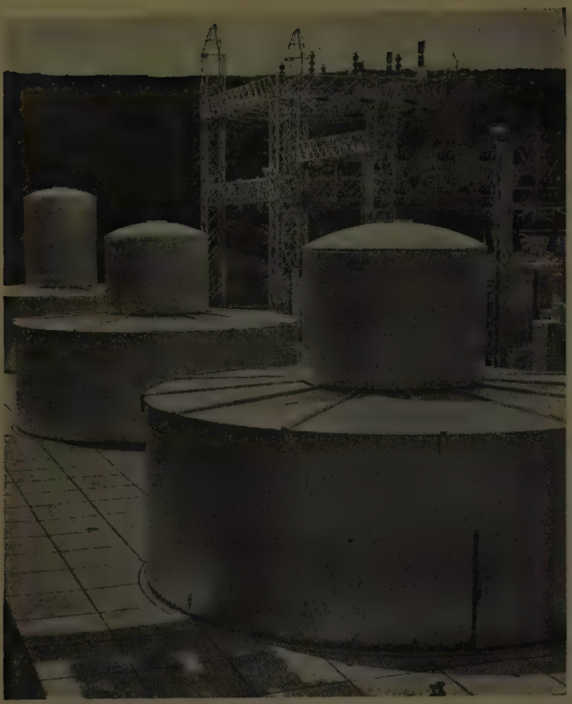


Figure 8. An outdoor umbrella-type generator installation

nated mica insulation are improvements in materials, processing, and coil treatment. The use of Fiberglas tapes and twines which became available in 1938 has practically eliminated the necessity of repairing or replacing end winding lashing and coil binder tapes from corona attack. Semiconducting compounds for surface treatment of high-voltage coils have suppressed corona activity so effectively both in the slot and on the end windings that its effect may be considered negligible. Many improvements in processing and manufacturing techniques have been made, which have raised the dielectric level of the insulation substantially and have produced a more uniform insulation. With the aid of modern quality control methods and rigorous statistical analysis, the quality level of the insulation is constantly checked and maintained to assure uniformity of product at a high dielectric level.

During the past several years, a number of testing methods have been developed to determine the quality of high-voltage insulation during production and during operation of the units. The most important of these are overpotential tests using direct current, slot discharge tests, and potential tests between turns for multiturn coils.

Overpotential Tests.[4] To ascertain that the winding insulation has a certain level of dielectric strength, an overpotential test is required. The d-c overpotential test is recommended because it is less damaging to good insulation for equal searching effect.

Slot Discharge Tests.[5] The slot discharge test is made with a specially developed cathode-ray oscilloscope equipment. An a-c potential equal to approximately line-to-ground operating voltage is applied to the winding. With the winding at operating potential, high frequency discharges between coil and stator core are observed on the oscilloscope. If the existence of discharging is indicated, the affected coil sides are located by probing the individual coil surfaces through the vent ducts.

Conductor Insulation Test.[6] The turn insulation of individual coils can be tested adequately with the high-frequency test set before the coils are wound in the machine; until recently no test method was known which would stress the turn insulation sufficiently after installation.

By using surge coils, a method has been devised whereby sufficient voltage can be induced in coils in a completed winding to stress turn insulation to several times normal operating voltage stress. This test is now made on all high-voltage windings of rotating machines which have multiturn coils during manufacture, and after the coil connections are made and the joint insulation applied.

With the advent of Thermalastic insulation, which is at present used exclusively on windings of the half-coil design, it can be expected that the application of this mechanically and electrically improved insulation will be extended to water wheel generator windings in the near future.

CONCLUSIONS

CONSIDERABLE PROGRESS has been made in bringing the reliability of hydroelectric equipment to a higher standard of quality than ever before. Devices to facilitate handling of parts have been provided to make inspection easier and to reduce maintenance cost to a minimum. The trend in large machines is toward enclosed ventilation systems with water-to-air heat exchangers. The umbrella-type construction now widely used results in lower maintenance and initial powerhouse costs. Figure 8 shows a typical modern outdoor umbrella-type installation.

Underground power stations now considered and being built will induce engineers to further thought and development of new designs which will make the hydroelectric power station a stronger competitor of steam power.

If minimum excitation devices are applied to water wheel generators, special precautions are necessary to avoid dangerous overvoltages with overspeeds equal to or greater than those which occur with full load rejection. The rotating amplifier pilot exciters also must be applied with caution due to the overspeed problem. It is recommended that the motor-generator-set Rototrol be capable of withstanding 50 per cent overspeed. Improvements resulting from manufacturing techniques and quality control have increased the reliability of these bearings.

REFERENCES

1. Performance of Vertical Waterwheel Thrust Bearing during the Starting Period, **C. M. Laffoon, R. A. Baudry, P. R. Heller.** *Transactions*, The American Society of Mechanical Engineers (New York, N. Y.), volume 69, May 1947, pages 371–379.

2. The Influence of Oil Film Journal Bearings on the Stability of Rotating Machines, **A. C. Hagg.** *Journal of Applied Mechanics*, The American Society of Mechanical Engineers (New York, N. Y.), volume 13, September 1946, page A211.

3. Modern Bearing Practice for Vertical Water Wheel Generators, **C. M. Laffoon, R. A. Baudry.** AIEE *Transactions*, volume 66, 1947, pages 363–71.

4. A-C and D-C Voltage Endurance Studies on Mica Insulation for Electrical Machinery, **G. L. Moses.** AIEE *Transactions*, volume 70, 1951 (*Proceedings T1–127*).

5. A Maintenance Inspection Program for Large Rotating Machines, **J. S. Johnson.** AIEE *Transactions*, volume 70, 1951 (*Proceedings T1–125*).

6. Detection of Turn-to-Turn Faults in Large High-Voltage Turbine Generators, **R. M. Sexton, R. J. Alke.** AIEE *Transactions*, volume 70, 1951 (*Proceedings T1–41*).

7. The Maintenance of Hydroelectric Generating Units, **A. S. Robertson, R. G. Standing.** AIEE *Transactions*, volume 66, 1947, pages 776–82.

8. Underground Hydroelectric Power Plants, **P. E. Gisiger.** AIEE *Transactions*, volume 69, part II, 1950, pages 1169–75.

A Sensitive Instrument Converter, the Induction Galvanometer

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Essentially a d-c to a-c converter, this induction galvanometer is admirably suited for making sensitive d-c measurements. Its operating frequency may be in the megacycle region if desired, the conversion energy gain is high, and ample signal is obtained for a-c amplification.

THE MOST effective method of sensitive d-c amplification for neasurement purposes is reliminary conversion to lternating current and mplification as alternatng current. The resolution ensitivity of an a-c amplifier, in good practice, is limited nly by fundamental noise levels, and conductive deoupling allows greater circuit flexibility for feedback. s a class, systems comprising a network loop of error onversion, amplification, phased rectification, and deenerative feedback to cancel the error are extensively sed in many effective devices for d-c amplification as a neasurement process.

Performance of such systems is largely contingent upon he detailed characteristics of the sensitive converter, and onsiderable developmental effort has been expended to roduce the several methods and devices in contemporary se, for example, the contact modulator and the thermally nodulated resistance. In some cases characteristic gain s obtained as in the saturable reactor amplifier, certain onlinear resistance element circuits, and impedance nodulators such as the capacitance modulator.

The method of choice naturally is determined by the letails of requirement, but in general the functional bjectives are: conversion should be efficient at levels ufficiently low to maintain an adequate feedback ratio; he converting device should not introduce spurious comonents additive to the input level; the converting device hould not be subject to excessive drift in terms of input evel; and the frequency of conversion should be suffiiently high for a high resolution sensitivity in terms of lifferential time.

Contemporary devices are probably most deficient in he last objective, being limited generally to audio freuencies. In closed-feedback systems the feedback period ust be made long with respect to the periodicity of modulaion, usually by peaking the amplifier, to avoid oscillation round the circuit loop or a step-function response. The ver-all system then will have a phase velocity insufficient or many requirements, or will be objectionable in applicaons where complicating corrective measures are admissible. lso, practical amplifier problems are considerably alleviated by increasing the operating frequency above the range of power-frequency hum, power rectifier harmonics, and microphonic impulses.

The induction galvanometer here described is a sensitive d-c to a-c converter having an advantage of high operating frequency—into the megacycle region if desired. With amplification reasonably peaked to the operating frequency, feedback periods in the millisecond region are obtainable readily. It has an inherently high conversion gain, of 10^8 order on an energy basis, and delivers a high amplifier input level. In practice the attendant circuit and component economy may be a considerable advantage.

GALVANOMETER STRUCTURE

THE INDUCTION galvanometer is essentially a conventional permanent-magnet movable-coil instrument structure, but has means for injecting an alternating component of magnetic flux into the permanent field flux path. The functional construction is shown in Figure 1 wherein the alternating field component is injected by an a-c magnetic shunt. When the movable coil is in the normal center-zero position the flux linkage is zero. But deflection causes the coil to link proportionally the alternating component of field flux, and an alternating component of potential having a magnitude and phase direction proportional to the degree and direction of deflection is induced in the coil. Thus deflection of the coil in response to a direct current produces an alternating potential which can be extracted by the external circuit for amplification.

Of necessity the connected external circuit presents an

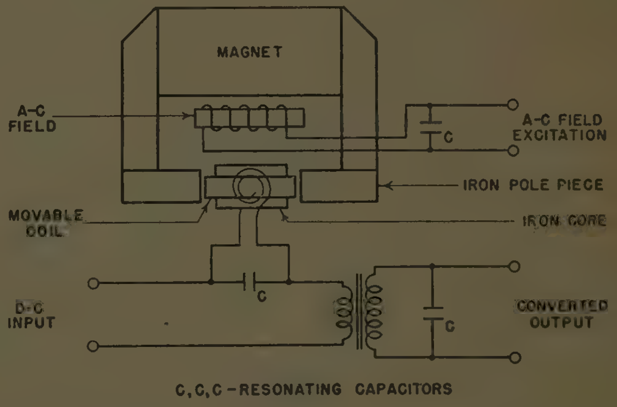

Figure 1. Structural diagram of the induction galvanometer

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ssentially full text of paper 51-183, "The Induction Galvanometer, a Sensitive Instruent Converter," recommended by the AIEE Committee on Instruments and Measureents and approved by the AIEE Technical Program Committee for presentation at e AIEE Summer General Meeting, Toronto, Ontario, Canada, June 25–29, 1951. cheduled for publication in AIEE *Transactions*, volume 70, 1951.

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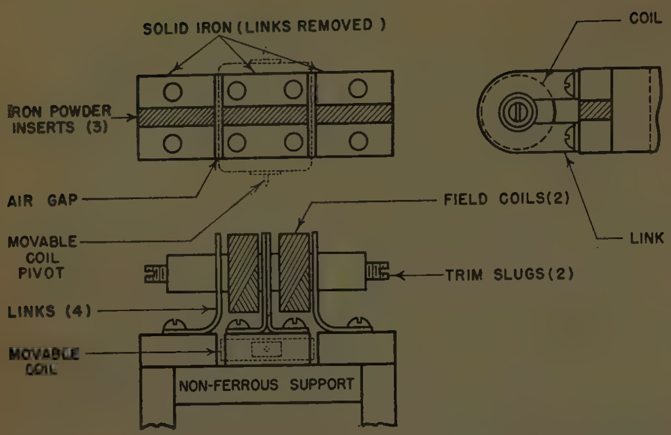


Figure 2. The pole structure with the iron powder inserts

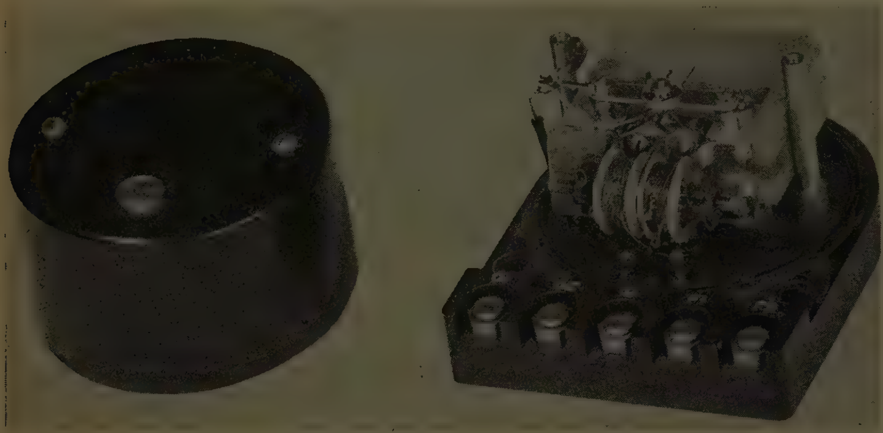


Figure 3. An induction galvanometer designed for conversion at 200 kc

effective a-c impedance across the coil, and an alternating component of current will circulate through the coil causing a force reaction with the alternating component of field flux. The induced potential is in quadrature with the field flux, and if the coil circuit is entirely resistive the alternating current will likewise be in quadrature and the reaction force will be entirely alternating. However, reactance in the coil circuit impedance will develop an in-phase component of coil current, and the coil will be subjected to a steady-state component of parasitic torque, which must be minimized. The torque appears as mechanical stiffness, similar to that imposed by a mechanical spring, but may be of either sign, positive or negative, when the coil circuit is inductive or capacitive. Therefore, it is essential that the phase angle of the coil and the connected circuit be considered.

Actually the reaction torque effect is useful because the coil circuit can include a resonated transformer which can be trimmed to cancel the torque of the filaments required for conductive connection to the coil. Transformer tuning thus serves as an adjustment to the point of infinite sensitivity by virtue of an infinite net mechanical compliance, or as close an approach as practical permanency of adjustment will permit.

The developed alternating coil potential is directly proportional to frequency, whereas the reaction force is a current-flux product. Thus, for a constant conversion sensitivity the alternating flux level may be reduced by raising the operating frequency, and the torque effect reduced in proportion. In fact, the operational quality of the system is proportional to increasing frequency until limited by some secondary consideration such as losses in the field structure or the movable coil.

The solid iron flux paths normally used in d-c instrument structures are not efficient for the high-frequency component of flux and, conversely, magnetic materials good at high frequencies have permeabilities insufficient for the relatively high level of steady flux from the permanent magnet. It is thus necessary to have a composite magnetic structure including materials individually efficient for both components of the field flux. Figure 2 illustrates a composite pole structure in which inserts of high-frequency material, iron powder-resin binder compacts, are included in each pole piece and the core.

In this arrangement the inserts are excited by links connected to the pole and core faces, forming single-turn loops around the inserts by conduction through the poles and the core. The outside ends of the links are coupled to a field coil connected to the high-frequency excitation source and resonated to the operating frequency. The flux is air-returned as is permissible at higher frequencies, and will not return in any appreciable amount through the solid iron and magnet structure. A compact design for tightness of coupling between the field coil and the inserts is desirable to minimize leakage reactance which would cause phase shift. Particularly the line impedance of the links should be kept to a minimum consistent with the practical design of the galvanometer.

In the operating circuit both the movable coil and field coils are individually resonated to the operating frequency, and for small coil deflections the quadrature phase-shift characteristic of loosely coupled resonated circuits prevails. Thus the useful movable coil output appears in quadrature to the excitation, which permits the frequency-shift operating circuit described later.

Figure 3 shows the production design of the induction galvanometer in which the link and insert structure of Figure 2 is discernible. It is intended only as an error detector in feedback systems, and so is designed to have a minimum of mechanical restoring force; the conducting filament connections to the movable coil are as light as adequate mechanical strength will permit. Also, the angle of necessary coil motion is small, and a simple rectangular air-gap design is used instead of the usual radial design.

A zero corrector is included in the cover, but actually it serves only to adjust the filaments to the position of zero force when the coil is at the point of zero coupling.

GALVANOMETER PERFORMANCE

THE STRUCTURE allows some design and performance optimums not usual to d-c instrument mechanisms. or example: the small deflection angle allows concentra- on of the permanent magnetic field to a high density; ie movable coil carries no load such as a pointer or mirror, lowing an unusually light coil design having a low ioment of inertia; the alternating component of torque educes friction to an undetectable order, allowing pivot nd jewel bearings at sensitivities normally requiring a ispension design; and electrical cancellation of the lament torque provides resolution sensitivity as a function f adjustment rather than as a design limit.

The design of Figure 3 has an operating frequency of 00 kc, largely dictated by amplifier considerations. At nominal excitation level of 0.5 watt a 100-turn movable oil of approximately 50 ohms resistance will develop an utput potential of about 1.6 volts rms per degree deflection. he permanent field flux density at the coil is about 8,000 ausses, and the d-c sensitivity against the restraint of the onducting filaments is about 6×10^{-8} ampere per degree eflection. Neglecting electrical torque, the conversion ain, defined as the ratio of energy developed in the novable coil impedance (about 300 ohms) to the d-c energy roducing it, calculates on this basis to about 4×10^{10}.

Actually the figure of conversion gain is illustrative only ecause in operation the circuit may be adjusted for ancellation of the restoring force of the filaments, in which ase the gain is adjustable through infinity to a negative ign.

In practise the conversion gain is more than adequate o present other limitations even when used with an mplifier of comparatively low gain. In low range opera- ion at high response speed, thermal agitation of the novable coil is apparent, and imposes a noise level limit. Also, drift influences become apparent, mainly thermo- lectric potentials between the filament alloy and the opper in the coil and circuit connections; a special fila- nent alloy is used to minimize this effect. But other than n these respects performance appears to be a matter of critical adjustment, with a reasonable expectancy in terms of energy of about 10^8 minimum gain.

The major result of the high conversion gain is the large eedback ratio obtainable using an amplifier of nominal gain. This, in combination with the high phase velocity permitted by the high operating frequency, provides an unusually short feedback period for a system including mechanical motion in its operating cycle. For example, an amplifier input resolution of 1 millivolt a-c will require a galvanometer movable coil operating excursion of only a few seconds of angle. This, together with the relatively ow mechanical moment of the coil, is capable of exhibiting eedback periods in the order of a few milliseconds on input ranges compatible with drift influences. Feedback ratios as high as 10^6 are entirely practical.

The induction galvanometer as a converter could be used with the customary peaked amplifier, phased rectifier, and d-c degenerating feedback network to form a d-c amplifying system. But the quadrature phase relationship between the field excitation and the converted output to the amplifier led to the development of a frequency-shift system of operation that proved simpler and more effective than the usual magnitude system. In particular, it avoids a separate field excitation source. Also it is capable of adjustment to a condition of infinite effective gain with a nominal order of actual magnitude gain.

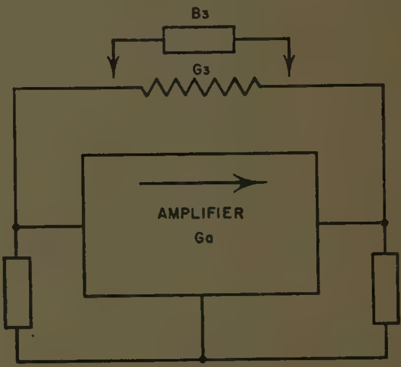
FREQUENCY-SHIFT SYSTEM

IN EXPLANATION, Figure 4*A* shows an idealized amplifier having a transconductance G_a of positive sign, coupled back upon itself by a pi-network comprising an output admittance Y_2, an input admittance Y_1, and a feedback conductance G_3. Such a system will oscillate when the amplifier transconductance is larger than the real component of the feedback admittance. The general admittance of the loop may be stated as

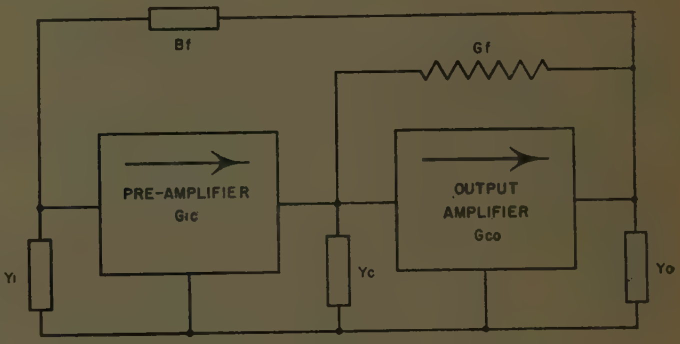
$$G_a - \frac{Y_1Y_2 + Y_1G_3 + Y_2G_3}{G_3} = 0 \tag{1}$$

which must have a real solution for oscillation. In practical amplifiers the transconductance is amplitude-limited by the energy output of the amplifier, so a solution can develop by an amplitude reduction of G_a provided the phase solution is real, which requires some frequency where the feedback network is entirely conductive. Thus the system, if capable, will oscillate at a frequency f_0 where the coupling network has a zero phase angle, and at an amplitude of oscillation where G_a is reduced to equality with the transfer conductance of the coupling network.

When the input and output admittances are large with



(A) EXPLANATORY FREQUENCY—SHIFT OSCILLATOR



(B) ADDITION OF PRE-AMPLIFIER SECTION

Figure 4. Equivalent networks for frequency-shift system

respect to the feedback conductance, as is permitted when G_a is of a usual order, equation 1 may be approximated as

$$G_a - \frac{Y_1 Y_2}{G_3} = 0 \tag{2}$$

Now consider the addition of a susceptive feedback element B_3 in parallel with the original feedback conductance G_3. The simplified impedance of equation 2 now becomes

$$G_a - \frac{Y_1 Y_2}{G_3 + B_3} = 0 \tag{3}$$

The frequency of oscillation will shift now to a frequency where the input and output admittances will have a composite phase angle opposing that introduced by B_3, and a real solution demands that

$$\angle(Y_1 Y_2) = \angle(G_3 + B_3) \tag{4}$$

to keep the coupling network phaseless to match the phaseless amplifier transconductance G_a.

Y_1 and Y_2 are parallel inductance-capacitance circuits phase-resonant at f_0, and the frequency shifts in response to an appearance of B_3 in a direction and to a degree proportional to the sign and magnitude of B_3.

The induction galvanometer is applied to the circuit to effect a frequency shift in the manner of B_3. The galvanometer field circuit is included as part of the output admittance Y_2, and the movable coil as part of the input admittance Y_1. With both parallel-resonant and loosely coupled by a small movable-coil deflection, the feedback component due to deflection will be shifted in quadrature phase, and will appear as the susceptive feedback B_3. The equivalent B_3 component is zero with the movable coil at center position, and appears in sign and amount proportional to the coil deflection.

The conductive feedback element G_3 is still necessary to maintain oscillation, but only in sufficient amount to insure stable operation.

Figure 4*B* differs essentially from the explanatory circuit of Figure 4*A* in the addition of the preamplifier section G_{ic} effective upon feedback through the galvanometer coupling parameter B_f. This increases the sensitivity of the system to B_f without requiring an impractically low value of conductive feedback, G_f, for maintenance of oscillation. When B_f is zero the preamplifier section is quiescent, but the second amplifier section is in stable oscillation. Y_i, Y_c, and Y_o are the input, interstage coupling, and output admittances.

The general simplified impedance of the loop now is

$$G_{co} - \frac{Y_i Y_c Y_o}{G_{ic} B_f + G_f Y_i} = 0 \tag{5}$$

which is similar to that for the illustrative circuit, equation 3. The output section transconductance G_{co} is amplitude-limited as before, but the input section transconductance G_{ic} is normally constant because of the low input level. Note that when B_f is zero the expression neglects G_{ic}, but is much more sensitive to appearance of B_f because of the gain of the input section G_{ic}.

To complete the amplifying system the output admittance Y_o includes a frequency-discriminating rectifier to supply the d-c output in response to the frequency shift.

This amplifier system, having a large useful d-c output upon injection of a very small d-c input, is generally combined with degeneration by including a d-c feedback path in degenerative sense. The amplifier then serves as an error-resolver and may function, for example, as an automatic potentiometer. The error amplifier then need only have a high gain but not necessarily stability, gain producing the necessary stability by the feedback mechanism.

D-c degeneration may be applied in many forms familiar to practice, the simplest being a single resistance mutual to the input and output circuits. It may include functions of time integration or differentiation for damping or for control of response time. It may include motor-driven components such as a slide wire combined with reactive elements for damping. But in general the freedom with which various forms and amounts of degeneration may be applied successfully is contingent upon a high phase velocity in the error-resolving function; otherwise phase reversals may develop in the operating loop, leading to instability or limiting the designed response speed.

In any event, while the methods of degeneration are too numerous to discuss, a common requirement for high resolution sensitivity and phase velocity dictates the best obtainable performance in these respects for the broadest usage. To this end a practical design applicable to many degenerative systems is described without reference to any specific method of obtaining degeneration or any particular application.

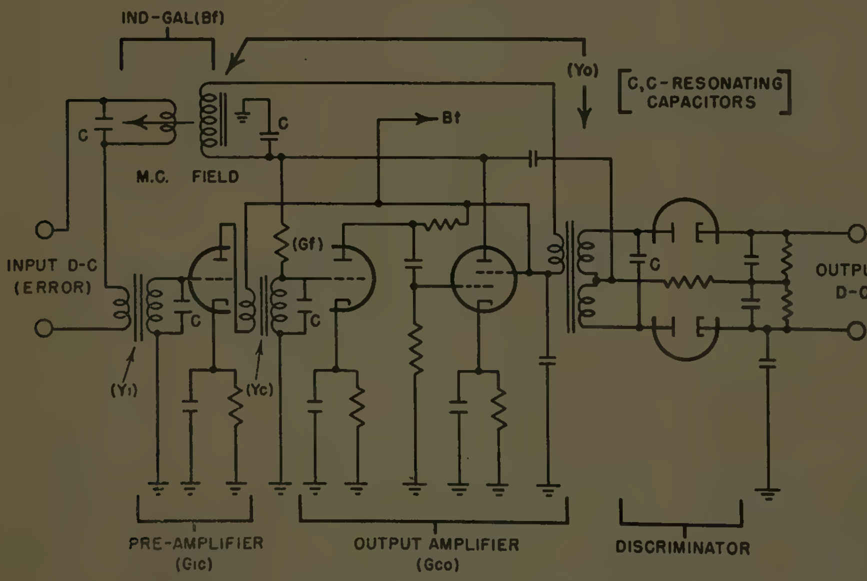


Figure 5. The amplifier used with the frequency-shift system

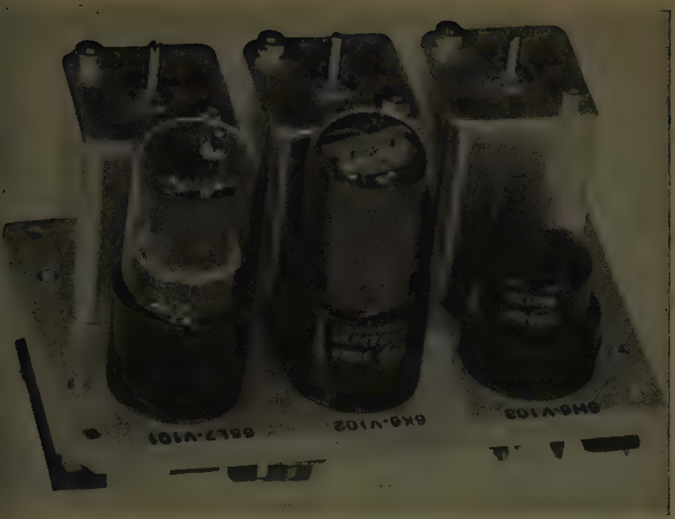


Figure 6. Amplifier strip using frequency-shift system

AMPLIFIER CIRCUIT

THE CIRCUIT OF the frequency-shift amplifier, including the output frequency discriminator, is shown in Figure 5 in which the components corresponding to the equivalent network elements are identified. The output-input d-c degenerative network with which the amplifier normally is used is not shown. The preamplifier is one-half of the dual triode, and the amplifier section is the other half of the dual triode and a power pentode in cascade. Two stages are required in the output section to phase the conductive feedback G_f in regenerative sense.

The input, interstage coupling and output (discriminator) transformers are of conventional cup-core construction, resonated to a center frequency of 200 kc with slug trimmers. The bulk of the output impedance is in the galvanometer field and its associated resonating capacitor, with the discriminator transformer coupled by insertion of its primary winding in series with the galvanometer field inductance, which phases the discriminator properly. The discriminator primary has relatively few turns, the number determining the coefficient of coupling between the separately resonated galvanometer field circuit and the secondary, which is connected to the dual diode rectifier.

The frequency discriminator is a conventional balanced type as commonly used in radio practice, and is phased by the capacitive connection to the output stage plate. The output direct current thus is balanced at center frequency and polarized with respect to frequency shift as the galvanometer deflects. As a power output element it is reasonably efficient, particularly when designed for supplying high-impedance load circuits. However, it is a peak rectifier and develops current pips having frequency components higher than the operating frequency, and so requires decoupling and by-passing not shown in the circuit. Otherwise interference with the sensitive input end of the amplifier may occur.

An amplifier strip comprising the Figure 5 circuit is llustrated in Figure 6. A complete production design nstrument amplifier, including the amplifier strip, power supply components, and a plug-in degenerating network, s shown in Figure 7.

The output is a current having a range of 1 milliampere into an external load not exceeding 5,000 ohms. The degenerating network unit, or "range standard," can be of either the potential-input or current-input type, and both types maintain balance in the input source circuit; in this sense the amplifier is an automatic potentiometer.

The galvanometer field and the discriminator transformer secondary are tuned separately to the same center frequency and coupled. The coupling coefficient may then be selected to overcouple slightly the two resonant circuits, to develop a double-peaked impedance and phase characteristic identified with the overcoupled condition. In the operating loop this compound impedance appears in shunt to the single-peak impedance of the interstage transformer, and by proper adjustment of the Q factors of the circuits in relation to the coupling coefficient an over-all flat-topped impedance and phase characteristic may be developed.

A flat-topped phase characteristic of the over-all total shunt impedance requires a relatively large excursion of frequency to produce a minor order of phase angle for balance against the feedback through B_f, and a correspondingly small appearance of B_f causes a large frequency shift. Theoretically, a truly flat top would make the system infinitely sensitive to B_f.

Overcoupling in proper amount thereby provides a method of simple adjustment to any desired incremental sensitivity about the center-frequency point and a relatively high sensitivity over reasonable excursions from center. Apparently the system is considerably superior to a conventional amplitude amplifier of similar component complement, unless regenerated for extra gain which is not as easy to adjust as simple resonant impedances.

Excess overcoupling resulting in double-peaking of the total impedance could cause instability by making the frequency of oscillation jump discontinuously from peak to peak, as commonly occurs in coupled oscillators. How-

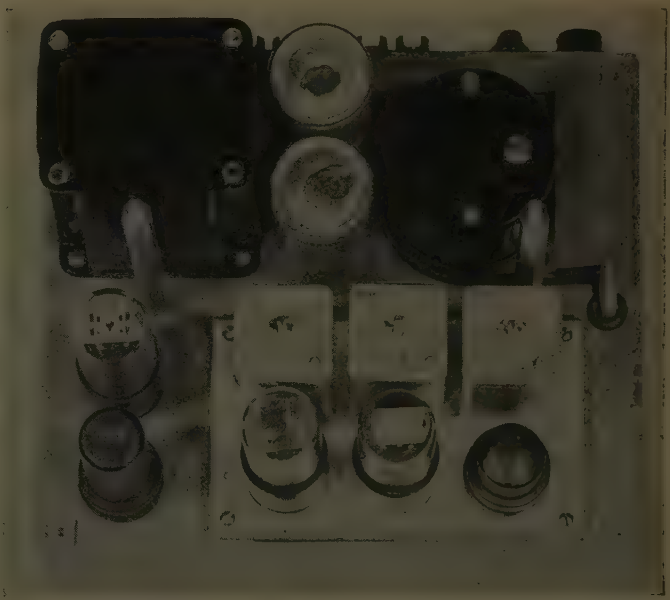


Figure 7. Complete amplifier including plug-in degenerative network and power supply

ever, in use the system includes a d-c degenerative feedback loop which exerts a corrective action. When the system is highly degenerated, excess overcoupling may, in fact, be perfectly stable, and is evidenced by reversal of the balancing action of the galvanometer; in this case the galvanometer exerts restraint upon the frequency shift rather than initiating the shift. Sensitivity in terms of galvanometer deflection is then past infinity and negative. But actually the ideal adjustment condition is still the point of disappearing galvanometer deflection, with ability of the system to accommodate excess overcoupling considered as an adjustment tolerance.

It is difficult to present a concrete analysis of the performance of a system where results are dependent almost entirely upon adjustment. Some adjustment tolerance must be determined as a permanent condition from the standpoint of engineering design, as a basis for evaluation. Upon this basis the performance details are offered:

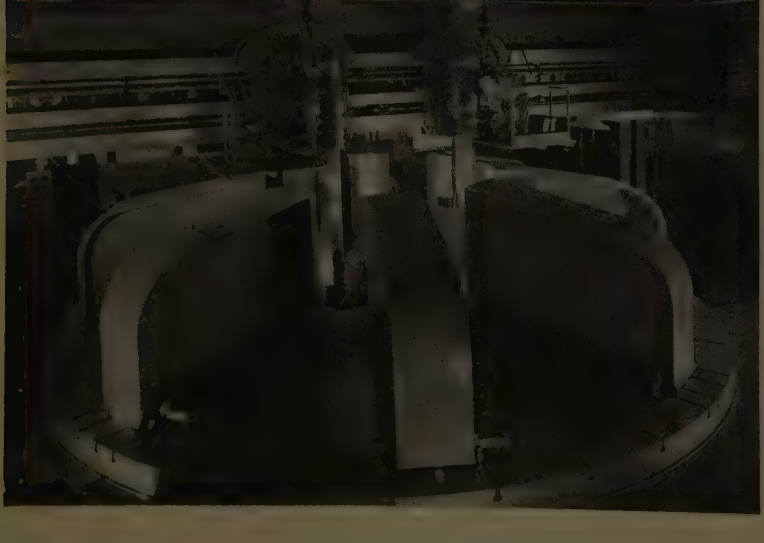
1. Galvanometer excursion for full output excursion is in the order of 5 seconds of angle. This has not been measurable by direct observation, but determined from the developed coil potential and/or the time-constant of feedback in a degenerated system against the mechanical moment of the coil.
2. Galvanometer resolution in terms of deflection and spring compliance is by far sufficient to make other limiting conditions, thermal drift for example, the effective limit upon the input sensitivity.
3. The small mechanical moment of the coil, the short excursion angle, and the high phase velocity of the amplifier operating at a high frequency combine to result in a short feedback period. For example, degeneration to an input range of 1 millivolt will result in a feedback period of about 0.1 second under a condition of considerable misadjustment.
4. When the amplifier is closely adjusted and critically examined, limiting noise due to thermal motion impacts upon the movable coil is observable. This is the generally recognized limit to the sensitivity of galvanometers beyond which amplification involves bandwidth considerations.

The short feedback period is perhaps most useful in providing stability when the feedback circuit is designed for differentiation or integration functions. For example, current may be time-integrated by feedback through a capacitor, and potential may be time-integrated by feedback through a mutual inductor. In such cases even short phase delays in the amplifier will lead to over-all feedback oscillation around the operating loop.

In feedback systems such as those to which this circuit is applicable, it has apparently only been appreciated recently that the sensitivity of error detection may be raised through infinity to function with stability on the negative side. The normal action of initiating control then has become restraint upon a system that spontaneously desires to initiate the change. Stability, whether operation is by initiation or restraint, is a function of the time parameters of the system, and transition through the point of infinite error resolution need include no discontinuous function leading to instability.

In the production design of Figure 7, a warm-up thermal drift having a stated 5-microvolt maximum essentially determines the resolution sensitivity of the system. This corresponds to about 0.1 microampere in the 50-ohm galvanometer movable coil. Zero adjustment of the galvanometer after warm-up will resolve most of this error. The working error is this resolution sensitivity figure added to the adjustment figure of the range standard resistors, which may be made 0.1 per cent of the range. Therefore, on ranges below about 5 millivolts or 100 microamperes, resolution sensitivity is limiting, and on higher ranges the standardized resistor adjustment is limiting. On still higher ranges the resolution sensitivity warrants a resistor adjustment accuracy beyond that normally feasible; for example, on a 1-volt range the possible precision is 5 parts per million.

40-Foot Mill Machines Arms for Hoover Generator



Radial arms of the upper bearing and thrust-bearing support for an 82,500-kva 100-per cent power factor 180-rpm suspended-type vertical synchronous generator for Hoover Dam are being machined on a 40-foot boring mill in the shop of the Allis-Chalmers Manufacturing Company, Milwaukee, Wis. The generator is one of two to be driven by 115,000-horsepower 480-foot head hydraulic turbines. When installed these will be the largest complete hydroelectric units ever built by one company. The two turbines will be duplicates of seven previous units built by Allis-Chalmers for this same installation, except that the spiral casing sections are of welded plate steel construction instead of cast steel as was used in the original units.

Forced-Oil Forced-Air Cooled Transformer Problems

A. L. HOUGH
MEMBER AIEE

THE ADOPTION of forced-oil forced-air cooling for large power transformers by the electrical industry as created a new problem for the operator of the equipment. The experience of this large utility has been that ie supplier has not furnished a self-cooled rating for his roduct. Thus, the problem of determining this self-ooled rating has fallen upon the purchaser and operator f the equipment.

It had been standard practice in our system to remove a rced-oil forced-air cooled transformer from service as on as all fans and pumps were shut down. This general ractice was adopted due to recommendations of certain f the manufacturers, regardless of whether the transformer as carrying load or excitation current only.

The problem appeared to consist of several prominent spects: (1) the determination of the self-cooled rating for arious banks, with field-testing under service conditions, nd calculations for other conditions not readily obtainable field tests; (2) the most suitable control and alarm stem for the installations; and (3) spare equipment such s fans, pumps, and so forth, required.

It was agreed that field test data should be obtained on ertain forced-oil forced-air cooled transformers. The anufacturers were contacted to ascertain the risks and ny special precautions that should be taken to carry out ie proposed field tests and were invited to be present for ie test run on the transformer which they had supplied. nitial tests were made in the late fall and early winter. he tests indicated that the transformers had a self-cooled ting of from one to ten hours and that it would be ad-isable to repeat the tests under the high ambient of summer onditions.

The test data obtained from the winter and summer sts were not readily adaptable for field use. The test ata were adapted for field use by the exponential equation r oil rise

$$= (\theta_u - \theta_i)\left(1 - e^{-\frac{t}{\tau}}\right) + \theta_i$$

here θ_o is the top oil rise at any time; θ_u is the final top oil se; θ_i is the initial top oil rise; t is the time in hours from e starting point; and τ is the exponential time constant hours.

A contact-making voltmeter was included in the control rcuit of the cooling auxiliaries to protect the equipment low voltage and to make the equipment autorestarting on recovery of sufficient voltage after loss of voltage.

The alarm system ultimately selected consisted of interposing relays in the motor circuits with alarm indication for both stopping and starting of the motors. A high top oil temperature alarm and a low oil level alarm were included also.

The forced-oil forced-air cooled transformers on this system have been supplied by five different manufacturers. The transformer suppliers did not manufacture the cooling equipment for their transformers. The coolers have been supplied by three different concerns and one concern has three different types of cooling equipment. The question of spare equipment such as fans, fan motors, pumps, pump motors, and so forth, is quite serious.

The field tests have indicated that it is unnecessary to remove a forced-oil forced-air cooled transformer from service immediately after the complete loss of the auxiliary cooling equipment. The time that the transformer can remain in service after the complete loss of cooling auxiliaries is dependent in general upon the load, both prior to and after the loss of auxiliaries, the oil rise above ambient, and the ambient temperature at time of the loss of cooling auxiliaries. The use of the exponential time temperature curve using constants derived from field tests appears to be a reasonably accurate method of determining the time available for emergency repairs or changes in system load distribution, to allow removal without too great a disruption to service.

The hottest spot indicators installed on the forced-oil forced-air cooled transformers on our system appear to be unreliable when their use is most desirable. This is undoubtedly due to the change in thermal characteristics, caused by the loss of the forced-oil circulation. One solution might be to have a separate hottest spot indicator and detector for this condition.

It would appear desirable to have the supplier of transformers of the forced-oil forced-air cooled type furnish a self-cooled rating for his product. This self-cooled rating should include the top oil rise and time constant and hottest spot rise and time constant at rated load.

The study indicated that there was no standard for the alarm system in stations where forced-oil forced-air cooled transformers had been installed. Remedial measures are being taken to set up uniform alarm systems along the lines indicated in this article.

REFERENCES

1. Cooling Power Transformers by Forced Circulation of Cooling Medium, **K. K. Paluev, L. H. Burnam.** AIEE *Transactions*, volume 62, March 1943, pages 215–21.

2. Interim Report on Guides for Overloading Transformers and Voltage-Regulators, **AIEE Transformer Subcommittee.** AIEE *Transactions*, volume 61, 1942, pages 692–94.

3. Selection, Design and Operation of Power Transformers, **F. A. Lane, I. W. Gross, P. A. Pugh.** *Electrical Engineering*, volume 69, July 1950, pages 600–04.

4. Predetermination of Self Cooled Oil Immersed Transformer Temperatures before Conditions are Constant, **W. H. Cooney.** AIEE *Transactions*, volume XLIV, 1925, pages 611–18.

5. Standard for Transformers, Regulators, and Reactors. *Standard C-57*, American Standards Association (New York, N. Y.), 1948.

6. Thermal Time Constants, **A. E. Kennelly.** AIEE *Transactions*, volume XLIV, 1925, pages 137–54.

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gest of paper **51-259,** "Operating Problems of Forced-Oil Forced-Air Cooled Transmers," recommended by the AIEE Committee on Transformers and approved by AIEE Technical Program Committee for presentation at the AIEE Summer General eeting, Toronto, Ontario, Canada, June 25–29, 1951. Scheduled for publication in EE *Transactions*, volume 70, 1951.

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Power-Line Synchronization Problems of Hum and Stability in Television

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Noise and instability in television pictures resulting from power-line synchronization are becoming a greater problem as networks expand. Some of the inherent difficulties and their causes are discussed in this article.

IT HAS BEEN common practice in experimental television to synchronize the frame repetition frequency with the frequency of power source. This practice removed one major cause of so-called "rolling hum" and will be discussed more thoroughly later. Because it does eliminate one source of rolling hum, commercial television cameras usually follow the practice of synchronizing the vertical sweep frequency with the power source frequency. There are some disadvantages in this method. One of them is that if the receiving device is not being supplied with the same power source as the camera pulse generator, and if the receiving device is susceptible to hum at its power source frequency, then the receiver kinescope will have a rolling hum pattern whether the camera sweep is synchronized with its power source or not.

Another difficulty is that in certain receivers employing the "high inertia scanning system," there is a tendency for the received picture to waver with fluctuations in the frequency of the camera power source.

A third factor has become important with the advent of network television programs. It is now possible for a program originating on the East Coast to be seen in the Middle West. Of course, synchronization must originate at the source of the picture. It is usually impossible for the sweep frequency of such a picture to be synchronized with a localized power system.

In this discussion, frequent reference will be made to the "camera." This should be interpreted as including the television camera and all pulse generation, sweep circuit, and video equipment associated with the camera.

NOISE PROBLEMS

CONSIDER A hypothetical case in which the camera and receiver are operating from the same source of power. The camera is synchronized to the power source which has perfect frequency stability and a perfectly sinusoidal waveform. The transmitted picture is entirely white so that any hum that appears in the video circuits shows up easily on the picture. Under these conditions, nothing will appear at either the receiver or camera monitor except the white picture with possibly a little stationary 60-cycle hum.

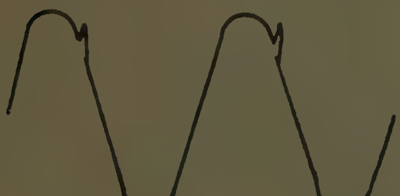

Figure 1. Pip on the power wave form

If, due to some condition in the generator, the power waveform develops an irregularity, perhaps of the form shown in Figure 1, it is possible that this sharp irregularity may, through capacitive or inductive effects, appear as a small irregularity on the grid of one or more video stages in either the receiver or the camera. Since the vertical sweep is synchronized with the power frequency, these pips appear at the same place on each vertical sweep.

Figure 2 shows the video signal with vertical blanking in relation to the vertical sweep waveform. Horizontal blanking pulses have been eliminated from the figure for the sake of clarity. The pip on the power waveform then appears as a motionless horizontal bar on the picture. The bar is illustrated in Figure 3. The bar could be either white or black, of course, depending upon the polarity of the pip voltage that appears in the video circuits.

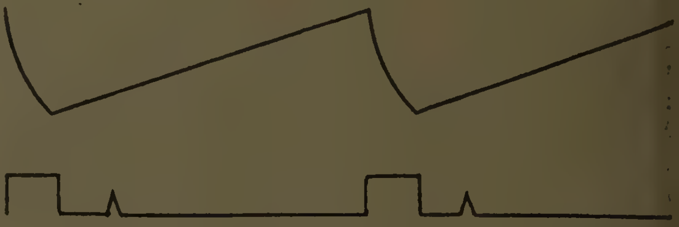

Figure 2. Video signal and vertical sweep relationship

It makes little difference if the pip is getting into either the camera video circuits or the receiver video circuits or into both. The result is still a motionless bar. Instead of developing just one irregularity, the power source could have many of these pips. In Figures 4 and 5, waveform irregularities due to coil slot saturation in the output of a diesel-driven generator are shown. Figure 4 is the wave-

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Essential text of paper 51-161, "Hum and Stability Problems of Power Line Synchronization in Television," recommended by the AIEE Committee on Television and Aural Broadcasting Systems and approved by the AIEE Technical Program Committee for presentation at the Great Lakes District Meeting, Madison, Wis., May 17–19, 1951. Not scheduled for publication in AIEE *Transactions.*

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The author is indebted to Dr. G. R. Town for the assignment of this problem and for much assistance, and wishes to acknowledge the valuable suggestions of Prof. R. C. Webb, the assistance and co-operation of L. L. Lewis, chief engineer of WOI and WOI-TV, the aid of John H. Bolton in organizing the material, and the help of C. K. Titus with photographic problems.

form of one 208-volt phase of a Y-connected generator. Figure 5 is the 120-volt waveform of one coil to ground. Each pip would have its own position on the power waveform and each would cause a hum bar. If receiver and camera were both on the same power source, the bars would be stationary on the picture at the receiver. This is often the case. Figure 6 illustrates horizontal bars resulting from the waveforms of Figures 4 and 5. Figure 6 was obtained by adjusting the black level and contrast of the video circuits so that the bars are greatly overemphasized.

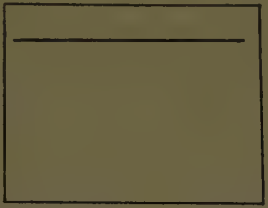


Figure 3. Horizontal bar

The hum bars are often not too objectionable if they are not allowed to roll. Many television viewers are either not aware of the presence of hum bars or are not aware of the fact that such bars should not appear in the picture. Oftentimes a little of the 60-cycle waveform appears in the video circuits. A little variation in the power waveform may appear without the appearance of the 60-cycle waveform, or both may appear, producing a gradual shading with black and white horizontal bars superimposed.

Next, it is necessary to consider the case in which the receiver and the camera are operated from independent power supplies. The camera is again synchronized with its power source. If an irregularity appears in the camera power source, it will be stable with respect to the vertical sweep frequency of the system and will appear as a stationary, horizontal bar in the receiver. If the receiver power source has an irregularity and there is a slight difference in the frequency of the two power sources, there will be a continual change in the position of the irregularity with respect to the vertical sweep of the receiver. This condition will produce a horizontal bar that continually moves up or down, depending upon the relative difference in frequency between the camera power source and the receiver power source. If the receiver power source has many irregularities, many rolling bars will be produced. If a certain amount of the 60-cycle waveform of the receiver source appears in the receiver video circuits, a continual change in the shading of the picture will appear from top to bottom, giving a rolling effect.

Thus far in the discussion, it has been assumed that the camera is synchronized to a perfectly stable power source, and the receiver and camera power sources may or may not be independent of each other. If the camera sweep-circuits are removed from the influence of any power source and placed under some form of independent control such as an incoming network program or perhaps a crystal oscillator, three different frequencies are involved. The first is the vertical sweep frequency which is determined by the previously mentioned independent control. The second is the frequency of the camera power source which may or may not be 60 cycles but is certain to be very close to that value. The third is the frequency of the receiver power source which is subject to conditions similar to those of the camera source.

If the receiver and camera are operating from the same power source with an irregularity in power waveform, there is no constant relationship between the power frequency and the vertical sweep frequency. The irregularity therefore will produce a rolling bar in exactly the same fashion as in the case when the camera was synchronized to the line but the receiver was operating on an independent power source. If the power sources of the camera and receiver are completely independent, two types of rolling hum may be introduced. The difference between the camera power source frequency and the vertical sweep frequency can produce hum that moves either up or down. Secondly, the difference between the receiver power source frequency and the vertical sweep frequency can also produce hum that moves either up or down. Thus it is possible to have bars moving up while other bars are moving down on the otherwise perfectly white picture. The introduction of 60-cycle sine wave in the video voltage from both power sources can introduce 60-cycle shading that moves up or down, or both simultaneously.

Thus, it is evident that independent sweep frequency control can lead to difficulties with hum originating in power systems. It should be remembered, however, that hum appearing in a television picture shows the existence of a defect in either the receiving equipment, in the camera, in the transmitting equipment, or in all three. The original system of power-line synchronization was adopted to make this hum less noticeable, but it contributed nothing toward removing the hum. This type of hum can be removed from video circuits, although sometimes with considerable difficulty. It is obvious that it must be

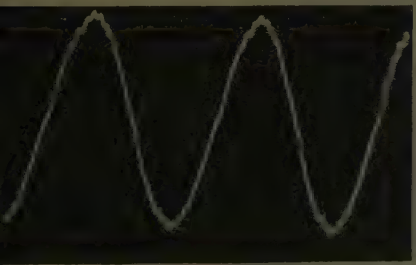


Figure 4. The 208-volt waveform

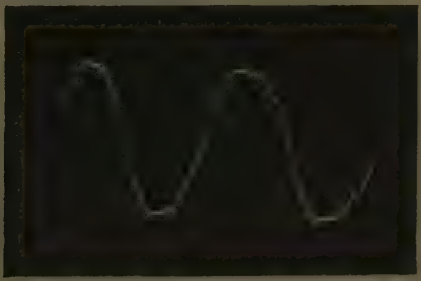


Figure 5. The 120-volt waveform

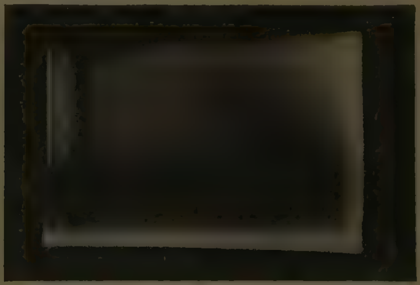


Figure 6. Resultant horizontal bar

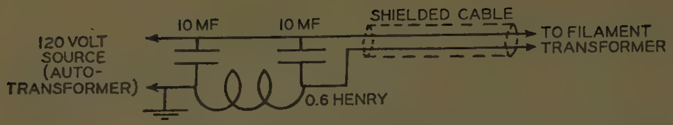


Figure 7. Line filter for feeding the filament circuit

removed before any type of sweep frequency control other than line synchronization is employed.

Almost all of the hum encountered in Figure 6 was removed by filtering the filament circuit of the video amplifiers immediately following the camera tube. This filter was a low pass pi section with values shown in Figure 7. It was designed to handle about 80 volt-amperes. An autotransformer was used to make adjustments in the input voltage. The inductance was found to be more effective in the ground lead, apparently because of circulating ground currents. Figure 8 shows the waveform of Figure 5 after filtering and Figure 9 shows the resultant effect on the white raster. It would have been better, of course, to correct the waveform of the entire system but that was economically impractical. It was found helpful, however, to shunt 100 microfarads of capacitance in delta across each of the three phases of the diesel-driven power system as shown in Figure 10. The capacitors did not help the coil slot saturation ripple, but they removed four sharp spikes in each cycle of the generator output. These spikes are not readily distinguishable on the photographs of Figures 4 and 5, but they did cause four slight tears in the television raster. These spikes apparently were not being introduced by the filament wiring because their appearance on the picture was not affected by the low-pass filter.

STABILITY PROBLEMS

CONSIDER THE effects of an unstable power source at the camera. It will be assumed that the camera's power source has no sharp irregularities but that it has an unstable frequency characteristic. Such instability could be caused by abrupt changes of load. All power sources have such a characteristic to a greater or lesser degree, and this characteristic causes power-line synchronization to be an unsatisfactory method of television sweep circuit control whenever receivers employing a high-inertia scanning system are used. A typical block diagram of a sweep frequency control device is shown in Figure 11. Many variations of this type of control are in use, so only a general discussion of the frequency controlling action will be given.

The master oscillator operates at a frequency considerably greater than the highest frequency to be used. In one particular case, this master oscillator frequency is 157.5 kc. The only requirement of the master oscillator is that its frequency be some multiple of 31.5 kc since that is the highest frequency employed in the pulse generator. By means of divider circuits, usually blocking oscillators, the master oscillator frequency is divided to 31.5 kc to obtain equalizing pulses. The 31.5-kc signal is then divided by two to provide horizontal synchronizing pulses at 15.75 kc. In another divider circuit a sample of the 31.5-kc signal is taken to obtain the 525th submultipl which is 60 cycles. (A sample as used in this discussio means merely a portion of the signal discussed, the use which has no appreciable effect on the circuit.) A sampl of this 60-cycle signal is taken to drive the vertical swee circuits. Another sample of the 60-cycle signal is fed t one side of a phase discriminator. A sample 60-cycl signal is taken from the camera power source and fed t the other side of the phase discriminator. When the tw 60-cycle signals are exactly in phase, the voltage outpu of the phase discriminator is zero. This is the equilibriu condition of the frequency control circuit. If the generato speed should decrease slightly, the generator frequenc would decrease and there would be an unbalance in th phase discriminator. Its output would then be a smal direct voltage. If the speed of the generator should increas slightly, its frequency would increase. The phase discriminator output would again be a small direct voltag of a polarity that would be opposite to that of the first The output of the phase discriminator is fed to the grid o a reactance tube that has a variable transconductanc characteristic. The result is that the reactance tube plat current changes with a change in phase discriminato output and consequently changes the frequency of th master oscillator. This action continues until the maste oscillator frequency again is a multiple of the generato frequency. Thus the master oscillator frequency move up and down in the same proportion as the power-lin frequency. There is, however, a small but finite amoun of time between the generator frequency shift and the frequency shift of the master oscillator. This is due primaril to the time constant of certain elements in the phas discriminator. The time of this lag is dependent upo over-all characteristics of the control system. It can b as great as 0.1 second.

If the generator is subject to constantly varying conditions of loading, it is possible that the line frequency wil be varying constantly up and down by a few tenths o a cycle. The extent of this frequency variation will depend

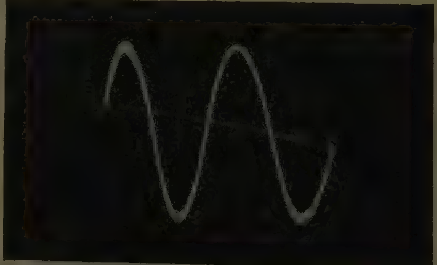


Figure 8. The 120-volt waveform after filtering

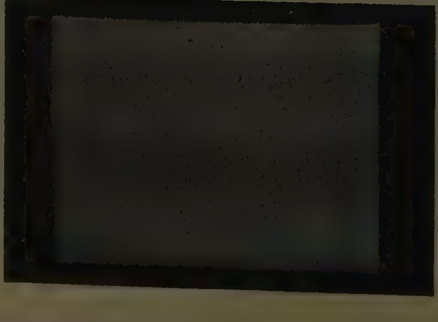
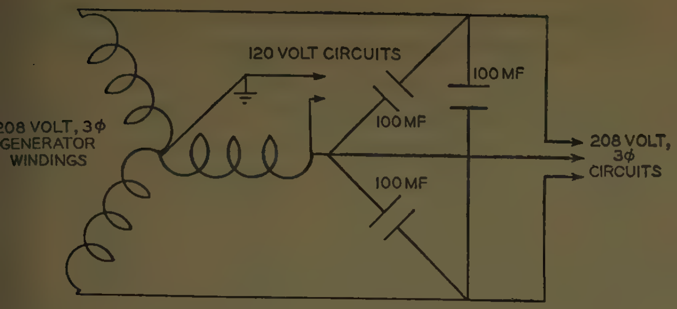
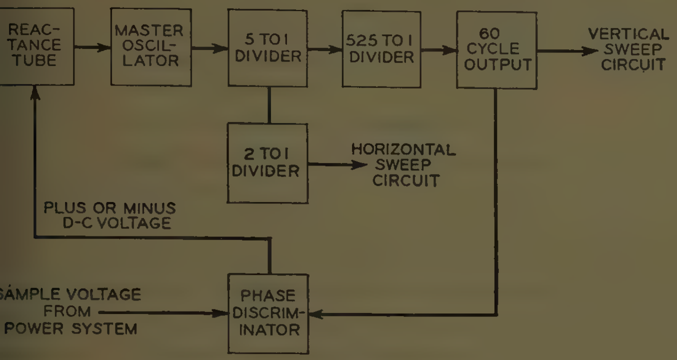


Figure 9. The white raster after filtering



igure 10. **Delta capacitors for filtering the power source**



igure 11. **Block diagram of a sweep frequency control circuit**

ipon the characteristics of the power source and upon the elative degree and frequency of load changes. For nstance, in one installation a television transmitter is eing supplied by a diesel-driven generator that is running t almost full capacity. The camera equipment is in the ame building and is supplied by the same generator. Vhenever the transmitted picture changes from white to lack or from black to white, the load change on the enerator is a considerable percentage of its full rated apacity. This is due to the modulation characteristics f the television transmitter. The line frequency changes re often quite rapid when a film with many abrupt hanges in average illumination is being transmitted. The master oscillator will try to follow these changes with he time delay inherent in the frequency control circuit. This effect can be seen by watching the left edge of the irst half line of the interlaced pattern as the illumination f the picture changes. The edge will move up to one-ourth of the total picture width as the transmitted picture oes from black to white.

Since all of the sweep circuits at the camera are con-rolled by the master oscillator, any slight variations in naster oscillator frequency will have the same effect in oth the television camera and the picture monitors. s an example, suppose that it is necessary to transmit one ertical line. The picture then would appear on the camera ube as shown in Figure 12. If an oscilloscope were placed n the video amplifier output circuit and then were adjusted o show the output of several horizontal sweeps, the re-ulting picture would be as shown in Figure 13.

The time increment between horizontal synchronization ulses may vary because the frequency of the master scillator may be varying. The time between the trailing dge (taken as a convenient reference point) of the horizontal synchronization pulse and the vertical pip representing the vertical line will be exactly the same for each horizontal line. If the sweep circuits of the kinescope are triggered by the same horizontal synchronization pulses as the iconoscope or other camera tube, then the vertical line will remain a vertical line even though the frequency of the master oscillator is varying constantly. The criterion for a stable vertical line reproduction is that the horizontal sweeps of the camera tube and the picture tube be in exact synchronization. This is true only if the horizontal synchronization pulses of both camera tube and picture tube occur either simultaneously or at least with a constant time delay between them. That is, the time delay between the first synchronizing pulse at the camera tube and the first synchronizing pulse at the picture tube must equal the time delay between the second synchronizing pulse at the camera tube and the second synchronizing pulse at the picture tube and so on ad infinitum. The conditions that must be met for stable picture reproduction are the same as for the reproduction of the single vertical line.

The final video output of a power-line synchronized system would appear on an oscilloscope as shown in Figure 14. Again the single vertical line is being transmitted. Vertical synchronizing pulses are not shown because they do not enter into the situation. The frequency of the horizontal synchronizing pulses varies, but the time increment between the trailing edge of the synchronizing pulse and the video signal representing the vertical line is constant in each case. It is assumed that as the signal of Figure 14 is received and detected, its shape will remain the same. Figure 14 represents also the signal as it appears in the receiver after detection.

A general block diagram of the sweep circuits of a receiver taking sweep synchronization directly from the horizontal and vertical synchronizing pulses is shown in Figure 15. After the synchronizing pulses are separated from the video signal, they are fed to a combination of a

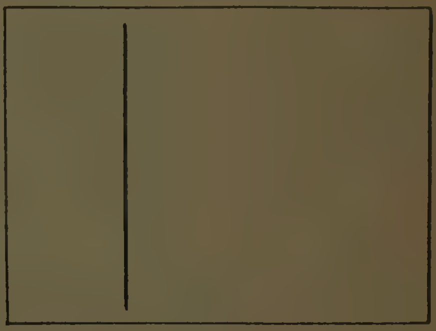


Figure 12. Picture containing one vertical line

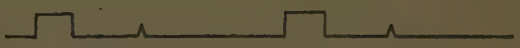


Figure 13. Video waveform for one vertical line picture

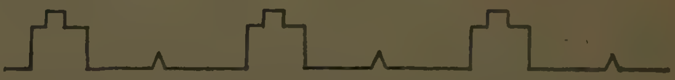


Figure 14. Transmitted waveform of the 1-line picture

differentiating and an integrating circuit. The differentiating circuit produces sharp pulses which are used to trigger the horizontal sweep circuits in the receiver. (Trigger, as used here, means to activate quickly the action of the driven circuit.) The integrating circuit is in operation all the time, but when the long vertical pulse occurs, its voltage builds up enough to trigger the vertical sweep circuit. In this manner both the horizontal and vertical sweep circuits are triggered in exact relationship with the horizontal and vertical synchronizing pulses coming in. This fulfills the requirements for a stable picture even though the frequency of the incoming synchronizing pulses is not absolutely constant.

The system just discussed is the one employed in the cheaper television receivers. There are certain inherent disadvantages in such a system. One of the most important of these disadvantages is the susceptibility to transient disturbances. Whenever the frequency of the horizontal synchronizing pulses from the transmitter varies, however, it is possible for this system to give a more stable picture than the more expensive receivers employing a high-inertia scanning system. This is true especially in the absence of interference and noise or when the signal at the receiver is very strong.

A general block diagram of the sweep system of a receiver using one type of high-inertia scanning is shown in Figure 16. The vertical synchronizing pulses are separated in much the same way as in the direct synchronization system. The horizontal synchronizing pulses are fed, after differentiation, into one side of a phase discriminator. The other side of the phase discriminator is fed by a free-running oscillator at 15.75 kc. This oscillator feeds the horizontal sweep circuits. The phase discriminator has an action exactly like that of the power-line synchronization circuit at the camera. Its d-c output controls the grid of a reactance tube which, in turn, controls the frequency of the horizontal oscillator. If the horizontal synchronizing pulse frequency is constant, the frequency of the oscillator is adjusted to the synchronizing pulse frequency. The advantage of this system is that if a few horizontal synchronizing pulses are destroyed by atmospheric noise or some other cause, those pulses will be supplied by the horizontal oscillator. That is why it is called "high-inertia scanning." It is possible for reasonably good pictures to be received under quite adverse conditions with the high-inertia system.

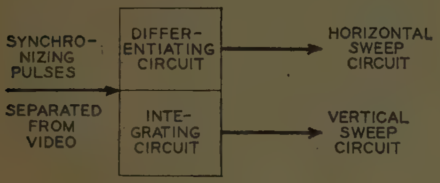


Figure 15. Block diagram of direct synchronization system

If the frequency of the incoming pulses were to change slightly and then remain at some new value, the horizontal oscillator would move to the new synchronizing frequency through the action of the phase discriminator. During the very short period of time in which this movement of the horizontal oscillator is taking place, the horizontal sweeps are being triggered by the output of the oscillator, but the oscillator is not in frequency synchronization with the incoming synchronizing pulses. The time differential between the pulse that triggers the sweep circuit and the video pulse representing the straight vertical line will be slightly different for each succeeding horizontal line. The line may momentarily appear slightly curved. If the frequency of the synchronizing pulses is constantly varying, the vertical line will appear to be constantly wavering. If the frequency shifting action is rather slow, the illusion of the entire line moving to the left or right may be created. Similarly, if a full picture is being transmitted, it is possible for that picture to waver horizontally from top to bottom. Also, the entire picture may move from left to right when the horizontal oscillator in the receiver is continually trying to follow the frequency of the incoming synchronizing pulses.

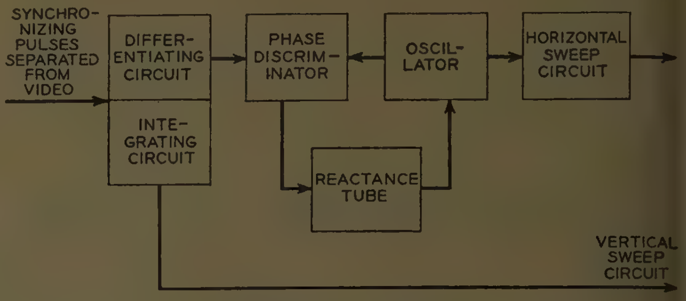


Figure 16. Block diagram of a high inertia scanning system

CONCLUSIONS

POWER-LINE synchronization of sweep circuits has no great disadvantages when the power system is stable and the receiver and the camera operate from the same power system. Whenever the receiver and the camera operate from different power sources, a more complex problem arises. If there is hum getting into the camera from its power source, stationary disturbances will be produced at the receiver. If there is hum getting into the receiver from its power source, the disturbances will move up or down. If the transmitter power source is unstable, the received picture may waver or move in receivers employing high-inertia scanning.

As long as the pulse generation equipment at the camera is stable, an independent sweep frequency source of good stability will present a good stable picture in all types of receivers. The instability of the power sources cannot produce waver or movement of the received picture. If hum is getting into the video circuits from the camera power source, then a moving disturbance will be produced at the receiver. If hum is getting into the receiver video circuits, a moving disturbance will again be produced. If the camera and receiver are operating on independent power sources and the hum has been removed at the camera, there is nothing to be gained by line synchronization. Receivers with hum will still have the same difficulties if the camera is power-line synchronized or not.

Proposed Symbols and Terms for Feedback Control Systems

AN AIEE COMMITTEE REPORT

Lack of a common language makes communication between engineers in allied fields difficult. A unified symbolism and terminology for feedback control is suggested here.

THE SUBJECT of unified or standard symbols and terminologies for any field of work is bound to be controversial. Especially is this true in the field of feedback control systems which has reached its present state of advancement through the work of so many diversified groups isolated from each other by the apparent difference in the physical nature of their problems. It has been realized only recently by the majority of workers in these fields that they are united by the similarity of principles which constitute the basic principles of feedback control. Those working in the process industries, with regulating systems, with governors, and with servomechanisms, have all contributed to the advancement of feedback control theory and over the past years have developed their own terms and symbols for use in analysis of their particular systems.

The abbreviated glossary given in Table I of this report emphasizes the need for a unified symbolism and terminology for feedback control systems. A still further indication of the need can be obtained by attempting to digest the material in various textbooks and technical papers published prior to the last year in the allied fields mentioned. Any one who has done this has been made painfully aware of the difficulty of communication between engineers in these allied fields due to a lack of a common language or, in other words, a unified symbolism and terminology.

The early acceptance of unified symbolism and terminology will promote ease of communication between engineers in related fields, ease in understanding and discussing new technical material, provide a common basis of understanding between a company and its customers, and will permit the writing of performance specifications for equipment that can be understood by workers in all of the related fields.

With these points in mind it is clear that the need for a standard nomenclature is of such importance to workers in all fields of feedback control system activity that any compromises necessary to attain this end are justified. It has been most gratifying to the committee to note the willingness and spirit of co-operation with which important contributors to the literature and technical advances of feedback control systems have accepted the recommendations of the committee as work has progressed and to note the conciliatory attitude displayed in general as comments were exchanged during the progress of the work.

The committee wishes to emphasize the importance of looking at these proposed symbols and terms in the light of their acceptability only, rather than whether they are the best possible choice from the viewpoint of the individual in any particular field.

The previous report of the AIEE Subcommittee, given as a conference paper at the Winter General Meeting in January 1950, presented in considerable detail a history of organized efforts toward a unified symbolism, including work done in The American Society of Mechanical Engineers as far back as 1936. This early report also covers quite thoroughly the philosophy behind the present committee's approach to the problem of establishing a unified nomenclature and the manner in which the task was approached.

The need for a set of symbols, both letter symbols and

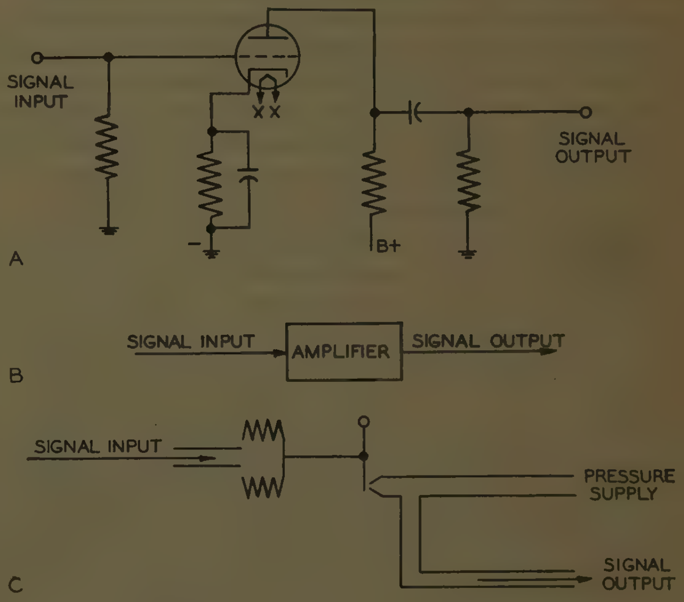


Figure 1. Electronic and pneumatic amplifier schematics with block diagram applying to either

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Full text of a district paper, "Proposed Symbols and Terms for Feedback Control Systems," recommended by the AIEE Feedback Control Systems Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Great Lakes District Meeting, Madison, Wis., May 17–19, 1951.

This is a report of the AIEE Subcommittee on Terminology and Nomenclature of the Feedback Control Systems Committee and the Working Group of the American Standards Association (ASA) Committee on Letter Symbols for Feedback Control Systems. AIEE Subcommittee members were: F. E. Crever, *Chairman;* W. R. Ahrendt, H. W. Cory, S. W. Herwald, A. G. Kegel, P. Travers, and A. J. Williams, Jr. Members of the ASA Committee who actively participated in meetings were T. A. Westover and S. P. Higgins, Jr. The American Society of Mechanical Engineers Committee on Terminology for Feedback Control Systems was represented by W. R. Ahrendt.

This report was prepared by H. W. Cory, Allis-Chalmers Manufacturing Company, Milwaukee 1, Wis.

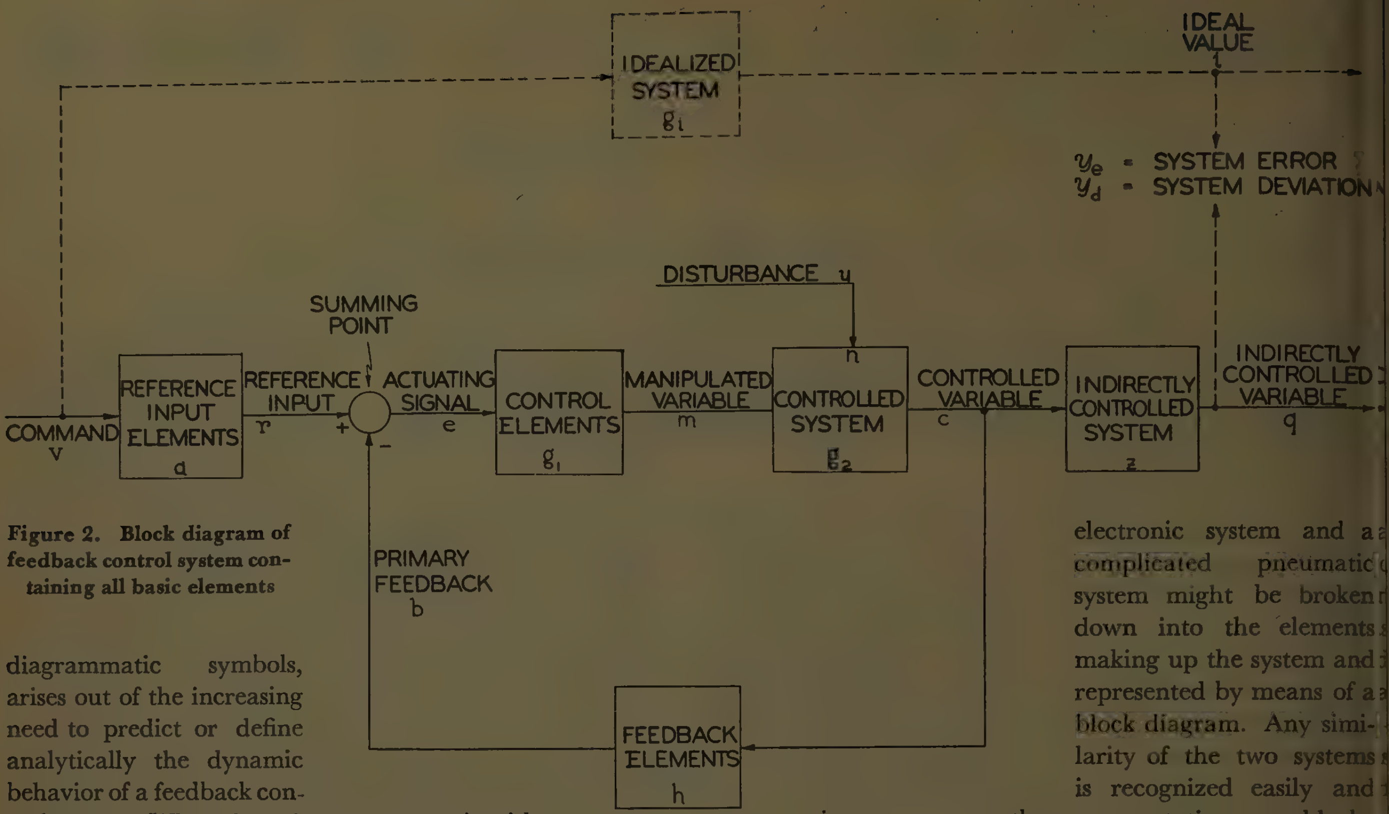

Figure 2. Block diagram of feedback control system containing all basic elements

diagrammatic symbols, arises out of the increasing need to predict or define analytically the dynamic behavior of a feedback control system. When the primary concern is with the dynamic behavior of a feedback control system, the use of a block diagram provides a simple means by which the functional relationship of the various components may be shown. The use of block diagrams is a logical development from the use of circuit diagrams or circuit schematics, which bear some similarity to the physical system, and flow schematics, all of which reveal the operation of a regulatory system much more readily than observation of the physical system itself.

The use of flow charts and such devices for analysis of a system, however, becomes too involved with the physical arrangement of the regulating system and for that reason does not show as clearly as the simple functional block diagram the similarity between different types of regulating systems nor does it show as clearly the fact that apparently different systems physically may be analyzed by the same techniques. A block diagram of a feedback control system represents the flow of the information and the functions performed in the system. It also may include dynamic characteristics of the components and of the system.

A block diagram is not involved with the physical characteristics of the system but only with the functional relationship between various points in the system and, therefore, reveals the similarity of apparently unrelated systems.

Figure 1*A* shows the circuit schematic for a vacuum-tube amplifier and Figure 1*C* shows the schematic of a pneumatic amplifier. Both of these amplifiers may be represented by the block diagram of Figure 1*B*. The lines in the block diagram of Figure 1*B* denote flow of information and the arrows the direction of the flow, and the block represents the function or dynamic characteristics of the components.

It is seen readily from Figure 1 that a complicated electronic system and a complicated pneumatic system might be broken down into the elements making up the system and represented by means of a block diagram. Any similarity of the two systems is recognized easily and in any case the representation would be much simpler and easier to work with.

Figure 3 shows the special junction point blocks necessary to indicate arithmetic manipulation. The equations accompanying the diagrams explain the operations involved and also indicate that the information flowing to and from these junction points must all be expressed in the same unit. This is not necessary in the use of other blocks such as shown in Figure 1*B*. These summing points may be extended to include the addition of more than two variables by merely adding more arrows to the circle with the proper sign.

The reason for this explanation here of the use of the block diagram is to emphasize the importance of establishing a block diagram which would include the basic elements of a feedback control system common to all of the varied fields of activity, now recognized as being related to feedback control systems, before beginning work on the search for unified symbols, terms, and definitions of terms.

The committee work proceeded on the basis of arriving at this basic block diagram and then establishing terms and symbols related to the block diagram and then defining these terms.

In the choice of letter symbols certain principles were established at the outset to be followed as closely as possible. Symbols were to be avoided which implied the mechanics of the control system, such as θ for angle, p for pressure, and so forth. It was also unanimously agreed that symbols which could be printed on the typewriter should be used as far as possible. Subscripts were also to be used as sparingly as possible to avoid confusion in printing. Also, symbols and terms were to be avoided which by long use in some other field had come to mean very specific things which would be at variance with use in feedback control system nomenclature.

After publication of the previous report considerable comment was received to the effect that it would be better o define the basic terms first before attempting to establish ymbolism of the form of the block diagram and accompanying letter symbols; also that definitions of basic terms be considered first. These comments were carefully considered by the committee; however, in the process of practically trying to work out the avenue of approach o the various terms, definitions, and letter symbols nvolved, it was found that some kind of master plan was necessary for the orderly progress of the work. In the actual order of procedure, the block diagram, and the accompanying letter symbols, all grew up together as an ffort was made to establish the typical block diagram which would answer the basic requirements of any feedback control system.

The fact that we have here presented definitions of basic erms, the terms themselves, letter symbols to be used to designate these terms, and the block diagram showing the relation of these terms and symbols to a complete feedback control system appears to justify the means to an end and makes the order of approach up to this point unimportant. Suffice it to say that the committee found it necessary to facilitate orderly thinking in arriving at acceptable defini- ions and terms to work with the block diagram.

Appendix I lists the proposed terms and accompanying definitions of basic feedback control system terms that have been agreed upon by the AIEE Subcommittee and American Standards Association (ASA) Working Group on feedback control system, letter symbols, terms, and definitions.

Figure 2 shows the proposed block diagram representa- ion of a feedback control system containing all basic elements. This block diagram contains all of the elements nvolved in a feedback control system and uses the nomenclature and symbols proposed in Appendix I. The letter ymbols are used to designate the value of variables such as command, reference input, primary feedback, and also as symbols for the characteristics of elements such as the reference input elements or the controlled system.

In using the block diagram to represent a linear feedback control system where the transfer functions of the elements are known, the letter symbol is capitalized, indicating that t is a transformed quantity. The lower-case symbols are used to represent any function in the time domain and ndicate simply that there is a functional relationship between the input to any given element and the resulting output. In many cases this relationship cannot be written explicitly but the symbols indicate that the functional relationship exists.

Where the letter symbol is associated with a variable quantity represented by lines in the block diagram, the ower-case symbol designates variables which are time unctions and the capitalized symbol denotes transformed variables which are functions of the operator p or of the complex variable s in Laplace transform. Similarly, the unctional symbols associated with the blocks of the block diagram indicate by the use of lower-case letters that a unctional relationship in the time domain exists between he input and output of this block and, by the use of capitalized symbols, that this relationship may be shown as a function of p, s, or $j\omega$.

Numerical subscripts are used to distinguish between blocks of similar functions in the same part of the circuit, for instance, the control elements designated by g_1 and the control system by g_2. If it were desired to represent the control system by two blocks to aid in representing relations between parts of the control system, these two blocks might be designated by g_2 and g_3. Similarly, if minor feedback loops are present, the blocks representing the feedback elements in the various minor loops might be designated by h_1, h_2, and so forth.

Figure 4 shows a simplified block diagram of a feedback control system with unity feedback showing that the use of the terms and symbols need not be changed for this reduction of the system. Note, however, that in the absence of reference input element the command and the reference input become the same.

As selection of terms and their accompanying definitions for the feedback control system represented by the block diagram progressed and comments on the work were exchanged with workers in the field, certain changes in the terms applied to the block diagram were found necessary. The complete block diagram in Figure 2 shows the input quantity to the reference input element as command. This was previously called desired value. The input quantity to the control element was changed from actuating error to actuating signal. The output of the feedback element, which is also the input to the summing point, was changed from feedback to primary feedback to distinguish this quantity from the output of the feedback elements of minor loops that might be present.

The concept of the idealized system g_i represented by the block enclosed with dotted lines on the block diagram was evolved in a search for a way to properly define system error. It was recognized that the actual system error of interest to one who is attempting to analyze, synthesize, or write specifications for a feedback control system is the deviation of the system output from some ideal or desired value. It also was realized that the output of the system (the indirectly controlled variable or controlled

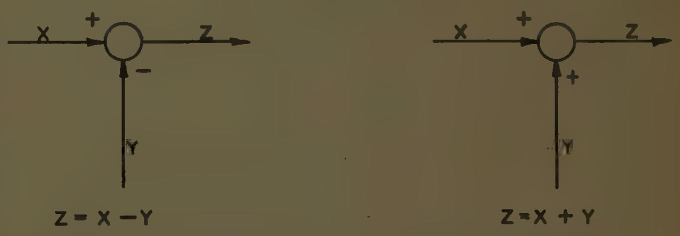

Figure 3. Arithmetic indication of junction point block

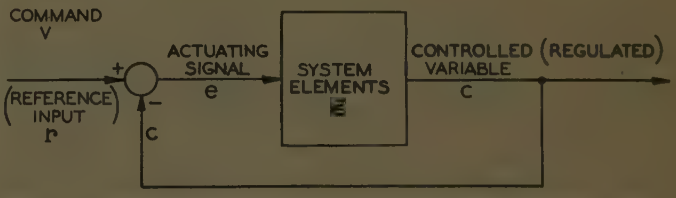

Figure 4. Simplified block diagram of a feedback control system with unity feedback

Table I. A Glossary of Terms and Symbols

Proposed Term and Symbol	Other Terms and Symbols Used
Command v	Input : desired value : set point : control point. Θ_i, d, Θ, i as subscript
Reference Input Elements a	Conversion elements : primary element : sensing elements
Reference Input r	Input : reference standard : desired value: set point. Θ, v, Θ_i, d, i
Actuating Signal e	Error : unbalance : actuating error correction : deviation. ϵ, Θ, Θ_e, u
Control Elements g_1	Amplifier : controller : servo amplifier : relay : error corrector. y, kg, h, μ, a
Manipulated Variable m	....
Disturbance u	Load disturbance : upset : noise : drift. l, d, n
Controlled System g_2	Process : plant : load. y, kg, h, μ, a
Controlled Variable c	Output : regulated variable : measured variable. Θ_0, 0, r, o as subscript
Indirectly Controlled System z	Process : plant : load
Indirectly Controlled Variable q	Output : regulated variable. 0_0, 0, r, o as subscript
Feedback Elements h	Feedback transfer function. y, kg, g, β
Primary Feedback b	Monitoring feedback : feedback. Θ_f
Summing Point	Error detector : error measuring means discriminator
Idealized System g_i	Ideal system : desired system : preferred system : reference system
Ideal Value i	Desired value
System Error y_e	Error : deviation
System Deviation y_d	Error : deviation

variable) may not bear any measurable relationship to the input (reference input or command). The idealized system can be understood to show the relation between the basic input to the system and the performance of the system in terms of output desired by the designer of the system or the purchaser of a system. This then would be the system agreed upon to establish the ultimately desired output or "ideal value" of the output of the system. System error then can be defined in terms of the ideal value and the ultimately controlled variable (this may be either the indirectly controlled variable or, in the absence of an indirectly controlled system, the controlled variable).

It was recognized also that the ideal value as shown on this diagram actually represented for many types of feedback systems the quantity known as the desired value. It was for this reason that the input to the reference input element was changed from desired value to command. The arrows and blocks associated with the idealized system, the ideal value, and the system error are shown in dotted lines on the block diagram as they do not exist physically in any feedback control system but for any specific problem will represent the system conceived in the mind of the designer or purchaser that will give the closest approach as a perfect system to the ideal value or desired output. In systems where the command is actually the desired value or ideal value, the idealized system would be represented by unity.

It was partly for the reasons associated with the idealized system and the final definition of system error and partly due to the many comments received objecting to the use of error in connection with the input to the control element that the term actuating error was changed to actuating signal. It was recognized that this quantity may exist in systems which are, in fact, operating without system error as defined in terms of the ideal value and the ultimately controlled variable.

The line and arrow representing disturbance with symbol u represents that disturbance which can be considered the addition of a variable into the control system, Figure 2. The symbol n denotes the functional relationship between the variable representing the disturbance and its effect on the control system and might be represented by a separate block and the output of the block fed into the system through another summing point Another type of disturbance in the system is of the nature of a change in parameter of various components or elements within the system and, in fact, results in a new system. This type of disturbance must be handled differently in analysis than the type of disturbance represented on the block diagram. The committee acknowledged the need for recognizing this type of disturbance and the proposed term and definition for this disturbance is given as item 11 in Appendix I.

The letter symbols used with the terms in the block diagram are wherever possible the initials of the terms themselves. This was obviously not possible in every case and symbols such as p which is associated with the differential operator, d for derivative, and so forth, were avoided. This restriction on the use of certain letters of the alphabet and the limited number of letters in the alphabet made it unavoidable to use certain letters having no direct relation with the term involved.

A glossary of terms and symbols used up to this time is given in Table I. This glossary is not complete but lists those terms and symbols (not necessarily together) that have had some frequent use. Only those terms which are shown on the block diagram in Figure 2 are listed. It should be noted that many of the proposed terms (and symbols) are those most commonly used in previous works.

The further work of the committee will be in accordance with the outline given in the previous report and suggestions received through the main AIEE Committee on Feedback Control Systems and through the ASA Committee and will proceed as follows:

Define Terms Descriptive of System Performance. So that uniform specifications may be established for feedback control system performance, such terms as accuracy, sensitivity, stability, stimulus, response time, transient response, droop, dead zone, dead time, control ratio, error ratio, and so forth, will be considered next.

Define Terms Descriptive of Component Performance. So that uniform specifications may be established for the performance of components to be used in feedback control systems and so that these specifications may be in a form that can be immediately used in system analysis, such terms as transfer function, amplification, response, and so forth, as referred to the system components will be considered.

A More Complete Glossary of Symbols and Terminology. A glossary as complete as possible will be compiled of presently used symbols and terminology cross-indexed with the recommended terms and symbols as soon as the work just mentioned is completed. The incomplete glossary which is presented in Table I emphasizes the need of standard nomenclature and the need of the complete glossary for ease of transition to the recommended symbols and terms.

Classification of Feedback Control Systems. To aid communication between engineers a great need exists for classification terms by which a complete system can be adequately and simply described. An attempt will be made to establish a system of classification of feedback control systems and then to establish and define terms descriptive of the various classifications. The classification might be on the basis of grouping under such headings as servomechanism, governor, regulator, and so forth, and might be subdivided under these groups according to degree of complexity and/or whether the feedback functions are proportional, differential, integral, and so forth.

This report is ended with a final plea for open-mindedness and a conciliatory attitude by all who are engaged in feedback control system activity as they realize the extent and nature of the compromises involved in arriving at any possible unified system of nomenclature for feedback control systems. The need for this unified nomenclature is great enough to bear repeating and can obviously be attained only if those working in the field will accept and use the proposed nomenclature.

The committee is continuing work on this project and comments to the committee on the subject will be appreciated.

It will be of interest to note that the new textbook recently published by Chestnut and Mayer uses the nomenclature proposed in the January 1950 report and that revised texts by Ahrendt and Taplin and also by Brown and Campbell will use the proposed nomenclature. The reviewers of all AIEE technical papers on the subject of feedback control systems are also being urged to encourage the use of the proposed nomenclature. The Navy Bureau of Ordinance is publishing a pamphlet on Servomechanisms using the proposed nomenclature.

Appendix I. Proposed Definitions of Basic Feedback Control System Terms

1. A *Feedback Control System* is a control system which tends to maintain a prescribed relationship of one system variable to another by comparing functions of these variables and using the difference as a means of control.

2. The *Controlled Variable* is that quantity or condition of the controlled system which is directly measured and controlled.

3. The *Indirectly Controlled Variable* is that quantity or condition which is controlled by virtue of its relation to the controlled variable and which is not directly measured for control.

4. The *Command* is the input which is established or varied by some means external to and independent of the feedback control system under consideration.

5. The *Ideal Value* is the value of the ultimately controlled variable that would result from an idealized system operating from the same command as the actual system under consideration. (The expression Ultimately Controlled Variable which is used here is a general term which refers to item 3 or, in the absence of a quantity corresponding to item 3, refers to item 2.)

6. The *Reference Input* is a signal established as a standard of comparison for a feedback control system by virtue of its relation to the command. (The term signal emphasizes that the quantity under consideration conveys information.)

7. *Primary Feedback* is a signal which is a function of the controlled variable and which is compared with the reference input to obtain the actuating signal. (This designation is intended to avoid ambiguity in multiloop systems.)

8. The *Actuating Signal* is the reference input minus the primary feedback.

9. The *Manipulated Variable* is that quantity or condition which the controller applies to the controlled system.

10. A *Disturbance* is a signal (other than the reference input) which tends to affect the value of the controlled variable.

11. A *Parametric Variation* is a change in system properties which may affect the performance or operation of the feedback control system.

12. The *System Error* is the ideal value minus the value of the ultimately controlled variable. (See note under Ideal Value.)

13. The *System Deviation* is the value of the ultimately controlled variable minus the ideal value. The system deviation is the negative of the system error. (See note under Ideal Value.)

14. The *Idealized System* is one whose performance is agreed upon to define the relationship between the ideal value and the command.

15. The *Controlled System* is the body, process, or machine, a particular quantity or condition of which is to be controlled.

16. The *Indirectly Controlled System* is the body, process, or machine which determines the relationship between the indirectly controlled variable and the controlled variable.

17. The *Feedback Controller* is a mechanism which measures the value of the controlled variable, accepts the value of the command, and, as the result of a comparison, manipulates the controlled system in order to maintain an established relationship between the controlled variable and the command.

18. The *Control Elements* comprise the portion of the feedback control system which is required to produce the manipulated variable from the actuating signal.

19. The *Reference Input Elements* comprise the portion of the feedback control system which establishes the relationship between the reference input and the command.

20. The *Feedback Elements* comprise the portion of the feedback control system which establishes the relationship between the primary feedback and the controlled variable.

21. The *Summing Point* is a descriptive symbol used in block diagrams to denote the algebraic summation of two or more signals. The direction of information flow is indicated by arrows and the algebraic nature of the summation by plus and minus signs.

22. A *Servomechanism* is a feedback control system in which the controlled variable is mechanical position.

Minimum Surface Leakage Distance in D-C Power Systems

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Compact machine designs require that minimum safe leakage distances on insulating surfaces be known. A number of factors which affect this distance in d-c systems have been studied and are the subject of this article.

THE DESIRABILITY of providing more compact installations of electric power equipment requires that studies be made of the dielectrics used to determine their properties and limitations. One important phase of this broad problem is the establishment of minimum safe leakage distances* for d-c power systems.

The information that is now available does not recognize the full effect of environmental conditions nor does it represent the limitations of the insulating materials. In an effort to establish reliable values for leakage distances, the factors which affect them must be determined and evaluated. A knowledge of these factors will lead to the establishment of minimum safe leakage distances which is mandatory if complete freedom from insulation breakdown is to be obtained in a compact design.

SURFACE LEAKAGE CURRENT

AN IMPORTANT factor in establishing the leakage distance for insulation is the magnitude and effect of surface leakage currents. The magnitude of these currents depends upon the characteristics of the surface, surface contamination, and the voltage gradient. Since the power loss due to the flow of the leakage currents is inconsequential in power systems, concern need be given only to the damage that these currents may do to the surface of the insulation.

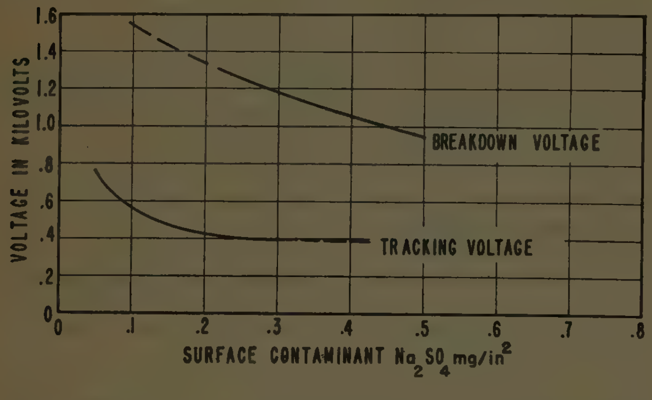

Figure 1. Effect of surface contamination on breakdown voltage and tracking voltage. Material—laminated glass phenolic; electrode spacing—0.5 inch; surface moisture—45 milligrams per square inch

The application of voltage of sufficient magnitude can cause a surface breakdown of the insulation. The carbonization or other damage to the insulation resulting from this breakdown voltage is caused by the surface leakage currents. Contaminating the surface of the material with a conducting electrolyte will reduce the magnitude of voltage required to produce breakdown, as illustrated by Figure 1.

The leakage current that flows across the insulation due to voltages of the order of breakdown voltage or higher, however, does not represent the minimum current required to damage the insulation. Assuming all other conditions constant, as the voltage gradient is reduced, the corresponding leakage current and resulting surface damage is reduced. In place of the deeply burned groove in the insulation, smaller charred islands or carbon tracks are formed. For any given material and environment the minimum voltage that will cause damaging leakage currents to flow is termed tracking voltage. The comparative magnitudes of this voltage and breakdown voltage are shown in Figure 1.

Although those voltages which are equal to or greater than tracking voltage but less than breakdown voltage cause only partial damage to insulation, the damage becomes cumulative. Repeated applications of the same voltage will cause ultimate failure; the higher the voltage is above tracking voltage, the fewer the number of applications required. This is illustrated in Figure 2. This curve was obtained by using the techniques and procedure outlined in the Appendix, except that the contaminant was reestablished after each application of the voltage. The normal tracking voltage for the material and conditions was 400 volts. The progression of damage resulting from repeated applications of a voltage above tracking voltage is shown in Figure 3.

It is important to note that the curve of Figure 2 represents the upper limit of failures. Certain uncontrollable factors, such as the imperfection of the surface of the insulation, can reduce this curve. A small scratch on the material was found to cause it to fail with two applications of a voltage 175 per cent of tracking voltage.

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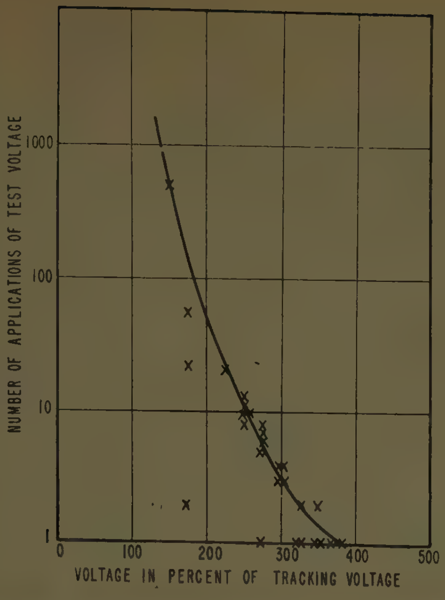
*Leakage distance is defined as the shortest path on the surface of an insulating material over which leakage currents may flow.

Essentially full text of paper 51-123, "Factors Affecting Minimum Surface Leakage Distances in Direct-Current Power Systems," recommended by the AIEE Committee on Rotating Machinery and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 22–26, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

J. E. Hart and **A. T. McClinton** are with the Naval Research Laboratory, Washington, D. C., and **W. W. Rosenberry** is with the Naval Engineering Experiment Station, Annapolis, Md.

Figure 2. Insulation breakdown resulting from accumulated damage. Material — laminated glass phenolic; electrode spacing—0.5 inch; surface moisture—45 milligrams per square inch; surface contaminant—0.2 milligram per square inch sodium sulfate



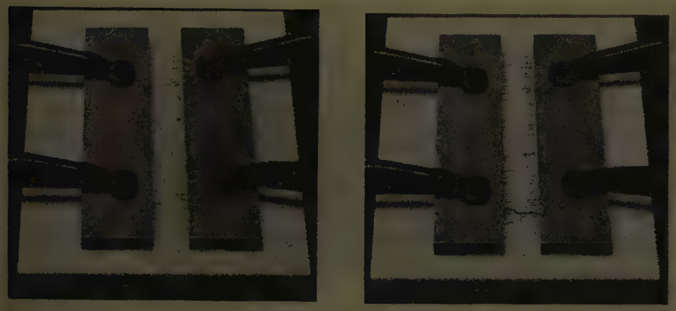


Figure 3. Accumulative damage to insulation resulting from application of a voltage 275 per cent of tracking voltage. Material—laminated glass silicone; electrode spacing—0.5 inch; surface moisture—45 milligrams per square inch; normal tracking voltage—510 volts

Before considering further the importance of this tracking voltage a brief discussion of the phenomena will be given. This may help to clarify the nature of results obtained showing the effect of environmental conditions, types and quantity of surface contamination, and type of insulating material.

When an insulating material between two electrodes has a continuous film of electrolyte on its surface and a voltage less than the tracking voltage is impressed, the resulting leakage current will have a magnitude proportional to the conductivity of the electrolytic film. However, the flow of current in this film will act to decrease the film area due to vaporization of the liquid by the Joule heat. Since the film is never of uniform thickness, this heating will cause random breaks in the continuity of the film and eventually its complete rupture. Figure 4*A* shows a typical current versus time curve for these conditions. The current rises abruptly to a peak when the voltage is applied and then decreases as the surface moisture begins to vaporize. As the film thickness decreases, breaks occur in the film surface. The current thereby decreases further until it finally approaches a negligible quiescent value. However, at the time of separation of the film small arcs may form on the surface of the insulation. If the energy in these arcs is low, as in the case of this example, no damaging tracks occur on the insulation. If a greater amount of contamination were employed, the severity of arcing would increase and the insulation would be damaged. Figure 4*B* is a representative oscillogram of the leakage current for this condition. (The irregularities in this current curve indicate arcing.) In this case the arc resisting ability of the insulation is exceeded and the insulation surface is damaged. Figure 4*C* is for identical conditions as 4*B* except that a material with a higher arc resisting ability was employed and no damage resulted. Thus it is seen that the tracking voltage is related to the arc resisting property of the insulating material.

This analysis of the effects of leakage currents on insulation and the relationships to environmental conditions indicates the following:

1. The minimum safe leakage distance is determined by the absence of damage to the insulation by leakage currents.
2. The magnitude of leakage currents is dependent upon the spacing of conductors on the insulation, that is, the leakage path, the voltage gradient, and the amount and nature of contamination.

SURFACE CONTAMINATION

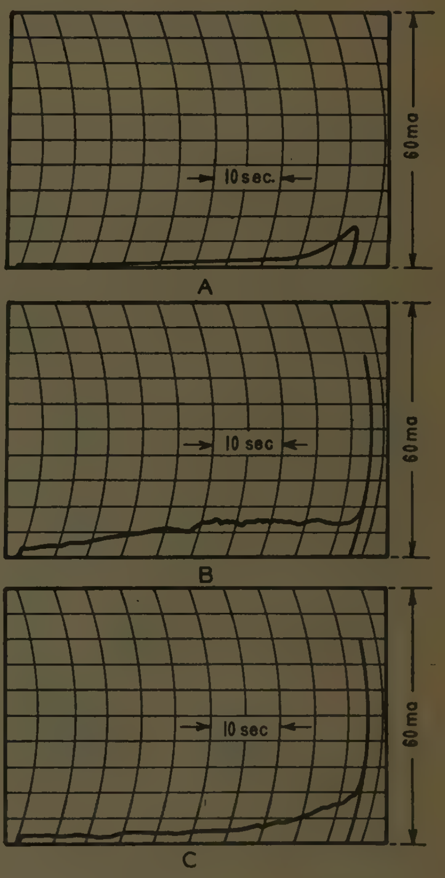
The dependency of minimum leakage distances on surface contamination emphasizes the need of specifying these distances on the basis of the maximum amount of contamination found where the equipment is to be used.

Figure 4. Transient leakage current.

A. Material—laminated glass phenolic; electrode spacing—0.5 inch; surface moisture—45 milligrams per square inch; surface contaminant — 0.02 milligram per square inch sodium sulfate; applied voltage—500 volts

B. Material—laminated glass phenolic; electrode spacing—0.5 inch; surface moisture—45 milligrams per square inch; surface contaminant—0.15 milligram per square inch sodium sulfate; applied voltage—500 volts

C. Material—laminated glass-melamine; electrode spacing—0.5 inch; surface moisture—45 milligrams per square inch; surface contaminant—0.15 milligram per square inch sodium sulfate; applied voltage—500 volts



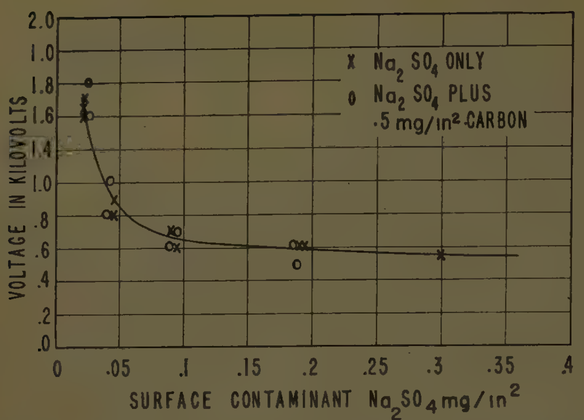


Figure 5. Effect of surface contamination on tracking voltage. Material—laminated glass-melamine; electrode spacing—0.5 inch; surface moisture—45 milligrams per square inch

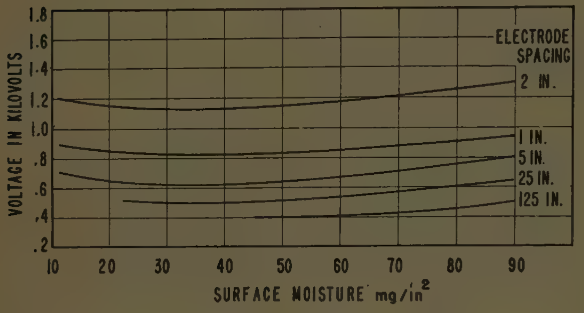


Figure 6. Effect of surface moisture on tracking voltage. Material—laminated glass-melamine; surface contaminant—0.1 milligram per square inch sodium sulfate

An analysis of the contaminants found on electric panels which had been in service in marine applications provides such a basis for this article. The results of these analyses are utilized as a range of concentrations of sodium sulfate. The leakage distances presented therefore may be extended to any application where the soluble contaminants can be represented as equivalent amounts of sodium sulfate. The relative effect of carbon or other insoluble contaminants on leakage distances will be indicated later.

An additional factor to consider is that of surface moisture. Under conditions of high humidity it was found that moisture condensed on the insulating panels. The combination of this moisture and the soluble contaminants provides the conditions most conducive to the production of damaging leakage currents.

Using the data from the chemical analysis and the techniques for measuring tracking voltage described in the Appendix, studies were made to determine the minimum leakage distances for variations in parameters of contaminants, ambient conditions, and insulating material.

MINIMUM LEAKAGE DISTANCE

THE VARIATION in tracking voltage as a function of the number of milligrams per square inch of sodium sulfate for a laminated glass-melamine insulation is presented in Figure 5. It can be seen that the tracking voltage for this material approaches a constant value as the concentration of contaminant is increased above 0.1 milligram per square inch.

The effect of the carbon which was found in the chemical analyses of the shipboard panels also is shown in Figure 5. A quantity of 0.5 milligram per square inch, which is greater than the maximum amount of the analyses, was added to the sodium sulfate solution. This had no measurable effect on the value of tracking voltage.

The effect of variations in the amount of surface moisture for a constant weight of sodium sulfate per square inch and several electrode spacings is indicated in Figure 6. The important consideration is that the tracking voltage has a minimum range for condensed moisture from approximately 20 to 40 milligrams per square inch. The amount of moisture which may be condensed on a panel under adverse conditions is also in this range. In view of this fact all basic tracking voltage tests were performed with a comparable moisture density.

A family of curves showing the variation of tracking voltage with electrode spacings for several values of contaminant is presented in Figure 7. The lack of any proportional relationship between the minimum leakage distance and the voltage is evident. Since the insulation is damaged by the arcs that form when the moisture film ruptures, it is the voltage gradient at the break in the film that is paramount in the production of damage. As the spacing between electrodes is increased the resistance of the surface film in series with the damage producing arcs is increased. However, this resistance is small compared to the resistance of the gaps, and therefore the increased leakage distance has only a small effect on the tracking voltage.

It is also evident from Figure 7 that for realizable ship-

Table I. Effect of Electrode Configuration on Insulation Breakdown

Configuration of Electrodes	Tracking Voltage	Number of Applications of 1,100 Volts to Cause Breakdown (Average of 3)
Stud to stud	550	2.5
Bus to bus	525	5.3
Positive bus to negative stud	575	3.3
Negative bus to positive stud	575	24.4

Table II. Minimum Permissible Leakage Distances in Inches for Various Conditions

Contaminant in Mg/in.² of Na_2SO_4	1,000 Volts				500 Volts				250 Volts			
	0.3	0.2	0.1	0.05	0.3	0.2	0.1	0.05	0.3	0.2	0.1	0.05
Laminated Glass-Silicone	*	*	*	0.75	0.25	**	**	**	All less than 0.25			
Laminated Glass-Melamine	*	*	1.3	0.6	0.35	0.25	**	**				
Laminated Glass-Phenolic	*	*	*	2.0	1.5	1.3	0.25	**				
Asbestos Phenolic	*	*	*	2.0	0.75	**	**	**				
Cotton Phenolic	*	*	*	*	*	*	0.7	**				
Silicone Rubber	1.5	0.9	0.25	**	**	**	**	**				
Hard Rubber Selected Type	*	*	*	*	*	*	1.6	0.25				

* Greater than 2 inches. ** Less than 0.25 inch.

board contaminants there exist definite upper limits of voltage if the specified leakage distances are to be held to a reasonable maximum value. The value of these limiting voltages depends, however, on the type of insulation material employed. By employing materials with characteristics which are improved over those of existing insulation, reductions of the minimum leakage distance will be possible. A few test points obtained from a sample of laminated glass-teflon illustrate this. A comparison of these results with those for glass-melamine, Figure 8, reveals not only the quality of this material but, of greater importance, the desirability of recognizing the minimum permissible leakage distance for each insulating material. The use of superior insulating materials thereby permits the reduction in size and weight of electric installations.

Variation of the ambient condition of temperature and relative humidity was found to produce no measurable effect on tracking voltage. The lack of any dependence is not surprising in view of the fact that tracking voltage is dependent to a large measure on the arc resistance of the material, conductivity of the electrolyte, and the moisture, none of which will be materially changed by the ambient temperature or humidity.

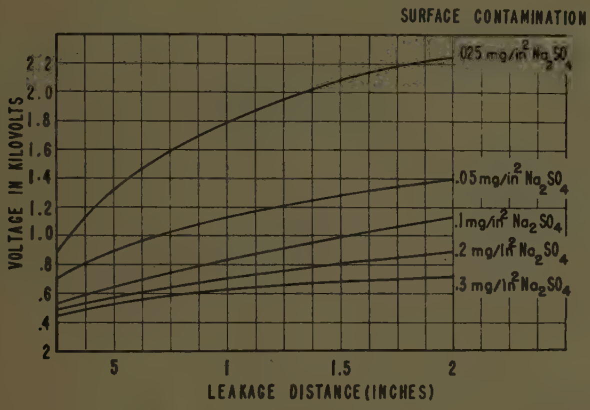


Figure 7. Tracking voltage as related to electrode spacing. Material—laminated glass-melamine; surface moisture—45 milligrams per square inch

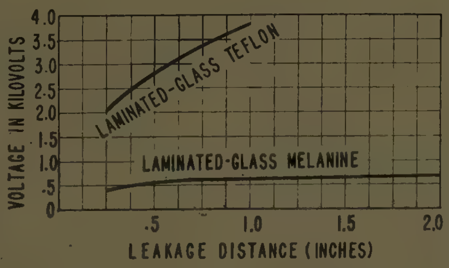


Figure 8. Comparison of tracking voltage for two materials. Surface moisture—45 milligrams per square inch; surface contaminant — 0.36 milligram per square inch sodium sulfate

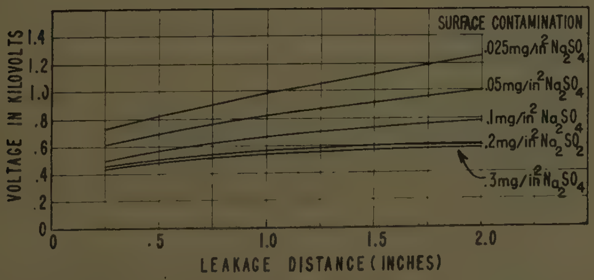


Figure 9. Tracking voltage as related to electrode spacing. Material—machined laminated glass-melamine; surface moisture—45 milligrams per square inch

Machining the surface of the insulation that is exposed to the leakage currents, on the other hand, had an influence on the minimum permissible leakage distance. Figure 9 shows the results for laminated glass-melamine. It was noted also that machining or otherwise altering the surface of the glass-teflon reduced the permissible voltage level shown on Figure 8 to approximately the same value as shown for glass-melamine. In general, machining of the glass laminated structures increased the minimum leakage distance. This evidently results from the presence of the exposed fibers of glass that either (1) are more susceptible to the arc than is the basic insulation, or (2) change the voltage gradient.

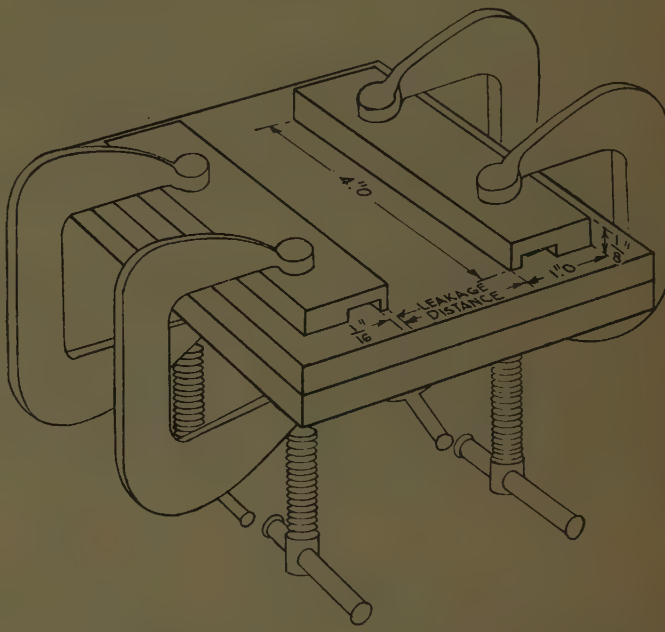


Figure 10. Insulation sample prepared for tracking voltage measurement

In addition to studying the effects of contaminant and environmental condition on tracking voltage, an investigation was made of the influence of electrode configuration. The arrangements used were two bus bars, one bus bar and a 3/8-inch stud, and two 3/8-inch studs. It was found that the tracking voltage was not affected by the geometry of the electrodes for those considered, but the number of applications of a selected voltage above tracking voltage to cause breakdown differed considerably for the several conditions. Table I shows these results.

SUMMARY

A summary of the minimum leakage distances for the several insulating materials investigated is presented in Table II. These data were obtained for d-c applications using the measuring techniques described in the Appendix.

The determination of safe minimum leakage distances for power installations is dependent upon the following considerations:

1. The minimum safe distance is dependent upon the leakage current across the surface of the insulation. The voltage associated with the minimum safe current, namely, tracking voltage, serves as a criterion for establishing this minimum distance. Exceeding this criterion either by increased voltage or reduced distance will result in ultimate breakdown and complete destruction of the insulating properties of the insulation.
2. The establishment of minimum safe leakage distances requires an accurate knowledge of the environmental conditions where the insulation will be employed. The deposition of water and soluble conducting contaminants, such as sodium chloride and sodium sulfate, will affect the tracking voltage greatly.
3. The arc resisting qualities of an insulating material will largely determine the safe minimum leakage distance.

Further investigation should be made to determine the factors affecting leakage distances in a-c systems and the relationship to d-c values. Surge voltages and the benefits derived from barriers also should be analyzed to add further knowledge to the limitations of insulated structures.

Appendix. Measurement of Tracking Voltage

Tracking voltage is defined as the minimum voltage which will cause damage to the surface of an insulating material for a given set of conditions. The procedure for determining a tracking voltage value is: a sample of the insulation to be evaluated is prepared by clamping a set of copper electrodes (bus bars) on its surface a measured distance apart. The surface between the electrodes is washed with distilled water and allowed to dry. A specific amount of contaminant, either dissolved or mixed with a specific amount of water, is spread over the surface of the insulation between the electrodes. A step-function d-c voltage is applied immediately to the electrodes and maintained until the leakage current reaches its quiescent value. This may be a period from 30 seconds to several minutes. After removal of the voltage the sample is lightly wiped with a sponge wet with distilled water and allowed to dry. Then it is scanned optically under a 15- to 20-power binocular microscope for evidence of tracking.

This complete procedure is repeated at successively higher voltages with the tracking voltage recorded as the minimum voltage for which tracking is observed. The entire procedure is repeated as necessary to obtain representative data for each point on a curve.

Several important details that are necessary to assure consistent and accurate results are: the under side of the bus bars is grooved (Figure 10) to prevent loss of the surface moisture by capillary action. The deposition of a specific amount of surface moisture is accomplished by the use of either a calibrated medicine dropper or a hypodermic syringe. A small camel's-hair brush prewetted is employed to spread the contaminating solution over the leakage surface. To provide uniform spreading of the surface moisture a nonionic wetting agent was added to the contaminating solution.

The power supply or voltage source used in these measurements should be well regulated and have a capacity of not less than 500 milliamperes. The transient response should allow a voltage variation of not more than about 2 per cent to eliminate errors which may otherwise be caused by the reduction in voltage gradient available when the leakage currents flow.

The resulting values of tracking voltage obtained on laboratory contaminated samples using the techniques described were compared with data obtained on panels removed from operating machinery. The results were in good agreement.

Master Timekeeper Varies Less Than One Second in 30 Years

A new and extremely precise master timekeeper was placed in operation recently at the Bell Telephone Laboratories, Murray Hill, N. J. It is expected to vary less than 0.0001 second per day; this corresponds to a precision of one second in 30 years. The secret of such split-second precision lies in four stable quartz crystals which vibrate constantly at a frequency of 100,000 cycles per second. The vibrations of these crystals control the frequency of a special electric current with a precision of one part in a billion. Two crystal units are visible in the picture; one at the extreme left and the other at the extreme right. The timekeeper is known technically as the Bell System Primary Standard of Frequency, and is the yardstick for the precise measurement of frequency and time throughout the Bell System. The apparatus is used by the telephone companies to monitor or regulate equipment for the coaxial cable and radio-relay television and telephone networks, as well as overseas, ship-to-shore, and mobile radiotelephone service. Radio broadcast network switching clocks are controlled also by this new device. The time-frequency measurement service is provided to the Consolidated Edison Company which uses it for regulating electric light and power services throughout the northeastern United States. The entire apparatus contains 600 electron tubes. To insure continuous operation, power is derived from storage batteries ordinarily charged from commercial power sources. A generator is provided for charging indefinitely if necessary. The equipment is housed in air-conditioned rooms where the temperature never varies more than two degrees.

INSTITUTE ACTIVITIES

Fall General Meeting to Offer Full Week of Sessions and Inspection Trips

A full week of stimulating technical sessions, interest-packed inspection trips, and relaxing entertainment awaits the AIEE membership at the Fall General Meeting in Cleveland, October 22–26. Both the technical program and the inspection trips were planned with the wide interests of the membership in mind.

Electric machinery, power system engineering, communications, control systems, and electronics are among the subjects scheduled for treatment at the technical sessions. Afternoon inspection trips will afford a cross-sectional view of Cleveland's varied industry with a number of scheduled trips from which to choose. Many of these trips will feature the latest developments in plant design, machine tools, and electric machinery.

Dr. T. Keith Glennan will deliver the keynote address at the general meeting at 10:00 a.m., October 23. The title of his address will be "Your Stake in Atomic Energy." A dynamic speaker, thinker, and doer, Dr. Glennan is on leave of absence from the president's chair of Case Institute of Technology to carry out his assignment on the Atomic Energy Commission.

INSPECTION TRIPS

In addition to seven scheduled inspection trips, arrangements have been made for informal inspections of other plants in the Cleveland-Lorain area by individuals or small groups. Members should check at the Inspection Trips desk for a listing of these unscheduled trips.

All scheduled trips will be held in the afternoons. Busses will load at and return to the Hotel Cleveland at times indicated for the various trips. A charge of $1.00 per person will be made to cover transportation costs to and from the inspection trip sites.

Because of security regulations at several of the plants on the inspection trip listing, members expecting to make the trips should bring along proof of United States citizenship (birth certificate, passport, naturalization papers, and so forth).

Chevrolet Plant of General Motors Company (Monday, October 22, 12:45 to 3:15 p.m.). A large portion of this plant having 30 acres of floor space is devoted to the manufacture and testing of Chevrolet's Powerglide transmission. In addition, other mechanical and pressed metal parts are manufactured here. Beside a host of applications involving the control and utilization of approximately 200,000 kilowatt-hours of electric energy per day, members will see many machines and tools for precision mass production of intricate metal parts.

Following this tour, there will be a short bus trip through Cleveland's industrial West Side, including brief stops at a new Ford Motor Company plant and the National Advisory Committee for Aeronautics Laboratory.

Nela Park—General Electric Company (Tuesday, October 23, 1:30 to 4:30 p.m.). Known as the "University of Light" because of its college-campus-like appearance, and the interest of its large number of scientists and engineers in the problems of production and utilization of light, Nela Park offers a program of full interest to AIEE members. Many types of lighting equipment and lighting applications will be demonstrated. Also, development laboratories and certain pilot manufacturing operations may be observed.

Reliance Electric and Engineering Company and Clark Controller Company (Tuesday, October 23, 1:30 to 4:30 p.m.). This combination trip offers an excellent opportunity to observe the manufacture and test of heavy-duty electric motors and industrial electric control. The Reliance plant manufactures a-c and d-c electric motors in the size range of 20 to 500 horsepower. Many are specially engineered for the steel, mining, paper, and machine tool industries. All phases of the motor manufacturing operation will be available for inspection.

Clark Controller manufactures both general purpose and specially engineered industrial electric control for a variety of applications. Some of the components produced are a-c and d-c motor starters, push buttons, limit switches, relays, contactors, and magnetic air valves.

Goodyear Tire and Rubber Company (Wednesday, October 24, 1:00 to 6:00 p.m.). This plant is at Akron, Ohio, approximately 30 miles from downtown Cleveland. The plant's principal activity is the manufacture of rubber tires for automobiles, trucks, aircraft, and off-the-road equipment such as tractors and earth moving machinery. In size, the tires range from a foot in diameter and weighing only several pounds to over

(*Continued on page 918*)

Future AIEE Meetings

AIEE Conference on Aircraft Electrical Applications (*page 919*)
Hollywood Roosevelt Hotel
Los Angeles, Calif.
October 8–10, 1951

AIEE Conference on Fractional Horsepower and Motor Applications to Refrigeration Equipment and Pumps (*page 923*)
Dayton Biltmore Hotel, Dayton, Ohio
October 11–12, 1951

Fall General Meeting
Hotel Cleveland, Cleveland, Ohio
October 22–26, 1951
(*Final date for submitting papers—closed*)

AIEE Conference on Feedback Control Systems
Haddon Hall Hotel, Atlantic City, N. J.
December 6–7, 1951

Joint AIEE-IRE Computer Conference (*page 923*)
Benjamin Franklin Hotel, Philadelphia, Pa.
December 10–12, 1951

AIEE Conference on Electronic Instrumentation in Nucleonics and Medicine
Hotel Commodore, New York, N. Y.
January 7–8, 1952

Winter General Meeting
Hotel Statler, New York, N. Y.
January 21–25, 1952
(*Final date for submitting papers—October 23*)

South West District Meeting
Jefferson Hotel, St. Louis, Mo.
April 15–17, 1952
(*Final date for submitting papers—January 16*)

North Eastern District Meeting
Binghamton, N. Y.
April 30–May 2, 1952
(*Final date for submitting papers—January 31*)

AIEE Conference on Electronic Converter Applications and Tubes
William Penn Hotel, Pittsburgh, Pa.
May 5–6, 1952

Summer General Meeting
Hotel Nicollet, Minneapolis, Minn.
June 23–27, 1952
(*Final date for submitting papers—March 25*)

The dynamometer room for testing Chevrolet Powerglide transmission at the Chevrolet Plant in Cleveland, one of the inspection trips scheduled for the Fall General Meeting

Tentative Technical Program

Fall General Meeting, Cleveland, Ohio, October 22–26

Monday, October 22

9:30 a.m. System Engineering

CP. Investment Costs for Use in Economic Comparison of Alternate Facilities.** *F. L. Lawton,* Aluminum Laboratories, Ltd.

51-358. Annual Carrying Charges in Economic Comparisons of Alternative Facilities. *P. H. Jeynes,* Public Service Electric and Gas Company

51-359. Operating and Maintenance Costs for Use in the Economic Comparison of Alternative Facilities. *W. E. Slemmer,* Ebasco Services, Inc.

9:30 a.m. Symposium on Polyethylene

CP. Polyethylene—General Characteristics, Production and Types.**

CP. Polyethylene—Mechanical and Physical Properties.**

CP. Polyethylene—Processing and Applications.**

CP. Physical and Electrical Characteristics of Polyethylene as Influenced by Temperature and Electrical Stress.** *A. J. Warner,* Federal Telephone and Radio Corporation

CP. Polyethylene.** *Victor Wallader,* Bell Telephone Laboratories, Inc.

9:30 a.m. Single-Phase and Fractional Horsepower

51-361. Steady State and Transient Synthesis of Three-Phase Reluctance Motors (Synchronous Motors without Field Excitation). *M. E. Talaat,* University of Pennsylvania

51-362. Characteristics of Reluctance Machines. *Chi-Yung Lin,* University of Illinois

51-363. Equivalent Circuits of Reluctance Machines. *Chi-Yung Lin,* University of Illinois

51-364. An Analysis of Un-excited Synchronous Capacitor Motors. *S. S. L. Chang,* Robbins and Myers, Inc.

9:30 a.m. Industrial Control

CP. High Voltage Motor Controllers.** *G. W. Heumann,* General Electric Company

51-376. A New 5000-Volt Air-Break Contactor for Industrial Service. *L. J. Goldberg,* General Electric Company

CP. High Voltage Air-Break Controllers.** *T. B. Montgomery,* Allis-Chalmers Manufacturing Company

CP. Low-Current Interruptions of High-Voltage Air-Break Contactors.** *C. A. Lister,* Electric Controller and Manufacturing Company

2:00 p.m. System Engineering

51-341. Evaluation of Energy Differences in the Economic Comparison of Alternative Facilities. *A. P. Fugill,* The Detroit Edison Company

51-360. Present Worth, or the Time Cost of Money, As a Factor in the Economic Comparison of Alternative Facilities. *P. H. Jeynes,* Public Service Electric and Gas Company

51-379. A Universal Power Circle Diagram. *R. D. Goodrich, Jr.,* United States Bureau of Reclamation

50-172. A Simple New Resistance Type A-C Load Flow Board. *W. E. Enns,* Portland General Electric Company. Presentation by title only for discussion

2:00 p.m. Symposium on Polyethylene

CP. Polyethylene—Evaluation for Field Wire and Cable.** *Milton Lipton,* United States Signal Corps Laboratories

CP. Polyethylene—Its Use in Power Cables.** *W. A. Del Mar,* Phelps Dodge Copper Products Corporation

CP. Polyethylene—Application to Power and Control Cable in Canada and England.** *H. D. Short,* Canada Wire and Cable Company

CP. Polyethylene—Application to Street Lighting, Line Wire, and Control Cable.** *J. M. Geiger, C. J. Nicholson,* Niagara Mohawk Power Corporation

2:00 p.m. Single-Phase and Fractional Horsepower

51-365. Single-Phase Motor Synthesis. *T. C. Lloyd,* Robbins and Myers, Inc.

51-366. Two-Phase A-C Servo Motor Operation for Varying Phase Angle of the Control Winding Applied Voltage. *M. A. Steinhacker,* Arma Corporation; *W. E. Meserve,* Cornell University

CP. Single-Phase Squirrel Cage Motor Theory.** *Edward Bretch,* Century Electric Company

51-319. Application of the Two-Reaction Theory to Electric Motors. *E. M. Sabbagh,* Purdue University

2:00 p.m. Industrial Control

CP. Synchronous Motor Control Design.** *R. C. Thompson,* Electric Machinery and Manufacturing Company

51-377. The Selection of Field Circuit Resistance for Synchronous Motors. *W. A. Thomas,* Case Institute of Technology; *O. D. Whitwell,* The Clark Controller Company

CP. D.C. Drives Applied to Deep Draw Presses.** *C. E. Robinson, A. P. Di Vincenzo,* Reliance Electric and Manufacturing Company

Tuesday, October 23

10:00 a.m. General Session

2:00 p.m. Conference on the Selection of Circuit and Lamp Designs to Conserve Critical Materials

CP. Lamps and Auxiliaries for Material Conservation and Economical Lighting.** *J. H. Campbell, E. A. Lindsay,* General Electric Company

CP. Electric Distribution and Control for Lighting Systems.** *R. N. Bell, W. H. Kahler,* Westinghouse Electric Corporation

CP. Economics, Operating and Control Experience with 480/277 Volt Lighting Systems.** *John Bos,* John Bos and Associates

2:00 p.m. Insulation and A-C Machinery

51-367. Slot Discharge Detection Between Coil Surfaces and Core of High Voltage Stator Windings. *J. S. Johnson,* Westinghouse Electric Corporation

51-368. Detection of Slot Discharges in High Voltage Stator Windings During Operation. *J. S. Johnson,* Westinghouse Electric Corporation; *Mead Warren,* Aluminum Company of America

51-369. Network Analysis of A-C Machine Conductors. *D. S. Babb, J. E. Williams,* University of Illinois

51-372. Selection of the Electric Motors for Oil Well Beam Pumping. *J. N. Poore,* General Electric Company. Presentation by title only for discussion

51-373. Turbo Generator for Use in Short Circuit Testing. *Sterling Beckwith,* Allis-Chalmers Manufacturing Company. Presentation by title only for discussion

51-384. Selection of A-C Motors for Driving Oil Well Pumping Units. *M. H. Halderson,* Phillips Petroleum Company. Presentation by title only for discussion.

2:00 p.m. Insulated Conductors

51-325—ACO.* The Problems Involved in Designing Connectors for Aluminum Cable. *Henry Dupre,* Burndy Engineering Company, Inc.

51-326. The Thermal Conductivity of Moist Soil. *A. S. Mickley,* Philadelphia Electric Company

51-327. Forced-Air Cooling for Station Cables. *R. W. Burrell, A. J. Falcone, W. J. Roberts,* Consolidated Edison Company of New York, Inc.

2:00 p.m. Management

CP. Work Simplification.** *Allan H. Mogensen*

Wednesday, October 24

9:30 a.m. Wire Communications Systems

51-328—ACO.* An Improved Polar Telegraph Relay. *W. D. Cannon, T. Rystedt,* The Western Union Telegraph Company

51-329. Public Address Systems in Generating Plants. *S. C. Bartlett,* American Gas and Electric Service Corporation

51-330. Bell System Cable Sheath Problems and Designs. *F. W. Horn, R. B. Ramsey,* Bell Telephone Laboratories, Inc.

CP. Engineering and Operation of Local Television Facilities.** *B. D. Wickline, J. E. Farley*

9:30 a.m. Transmission and Distribution

CP. Shunt Resistor Requirements for the Elimination of Ferroresonance.** *W. J. McKune,* The University of Texas

51-331. Analyses of Subsequent Faults. *H. K. Amchin,* American Gas and Electric Service Corporation; *E. T. B. Gross,* Illinois Institute of Technology

51-332. The Design of Capacitor Units for Series Connection. *B. O. N. Hansson,* Aktiebolaget Liljeholmens Kabelfabrik. Presentation by title only for discussion

51-333. Fast, Approximate Short Circuit Calculation on Secondary Networks. *J. Zaborszky, G. F. Cromer,* The University of Missouri

—PAMPHLET reproductions of authors' manuscripts of the numbered papers listed in the program may be obtained from AIEE Order Department, 33 West 39th Street, New York 18, N. Y., as noted in the following paragraphs.

—PRICES for papers, irrespective of length, are 30 cents to members (60 cents to nonmembers) whether ordered by mail or purchased at the meeting. Mail orders are advisable, particularly from out-of-town members, as an adequate supply of each paper at the meeting cannot be assured. Only numbered papers are available in pamphlet form.

—COUPON books in nine-dollar denominations are available for those who may wish this convenient form of remittance.

—THE PAPERS regularly approved by the Technical Program Committee ultimately will be published in Proceedings and Transactions; also, each is scheduled to be published in Electrical Engineering in digest or other form.

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* ACO: Advance copies only available; not intended for publication in *Transactions.*

** CP: Conference paper; no advance copies are available; not intended for publication in *Transactions.*

51-383. Transmission Systems of the Hydro-Electric Power Commission of Ontario. *J. E. Sproule, F. L. Code,* The Hydro-Electric Power Commission of Ontario. Presentation by title only for discussion

9:30 a.m. Power Generation

CP. Fire Protection in Electric Stations.** *H. A. Bauman, W. E. Rossnagel,* Consolidated Edison Company of New York, Inc.

CP. Hazards of Fire and Explosion are Reduced Through Developments in Transformer Design.** *W. W. Satterlee,* Westinghouse Electric Corporation

CP. Relation of Transformer Design to Fire Protection.** *E. D. Treanor,* General Electric Company

CP. Water-Spray Fire Protection for Generating Stations.** *K. P. Jones,* Dawson, Powell, Grinnell Company, Inc.

51-382. Progress in the Electric Power Industry. *I. E. Moultrop, G. A. Orrok,* Boston Edison Company. Presentation by title only for discussion

51-385. Electrical Features of Modern Automatic Hydro Stations. *C. L. Gamble, A. G. Mellor,* General Electric Company. Presentation by title only for discussion

9:30 a.m. D-C Machinery

51-370. Standard Temperatures of Reference for Efficiency Calculations. *P. L. Alger,* General Electric Company

CP. A New Method for Measuring Temperature in Electric Machinery.** *W. A. Thomas,* Case Institute of Technology; *R. J. Horvat,* Auburn Engineering Company

CP. Initial Inductance and Rate of Current Rise of D-C Motors and Generators.** *Subcommittee on D-C Machinery*

9:30 a.m. Co-ordinating Safety in Design with Field Operating Conditions

Introduction of Subject: Hendley Blackmon, Westinghouse Electric Corporation

Moderator of Panel: C. E. Ganther, Cleveland Electric Illuminating Company

Members of Discussion Panel

- Domestic and Commercial Applications
  - Design; T. H. Cline, Newark Stove Company
  - Field Operation: F. Hamburger, Jr., Johns Hopkins University
- Heavy Industry
  - Design: Edward Luoma, Reliance Electric and Engineering Company
  - Field Operation: H. H. Angel, Bethlehem Steel Company
- Utilities
  - Design: L. G. Smith; Consolidated Gas Electric Light and Power Company of Baltimore
  - Field Operation: W. C. Bryson, Duquesne Light Company

51-320. Ignition Delay in Oil Burners. *Ferdinand Hamburger, Jr.,* The Johns Hopkins University. Presentation by title only for discussion

51-380. Automatic Protection of Refrigerating Machines. *T. C. Johnson, G. C. Wedel,* General Electric Company. Presentation by title only for discussion

2:00 p.m. Television and Aural Broadcasting Systems

51-334—ACO.* Blocking Oscillator Design Considerations in the Television Receiver. *A. F. Giordano,* Allen B. Du Mont Laboratories, Inc.

CP. Systems and Equipment for Theater Television.** *R. V. Little,* Radio Corporation of America

CP. Video Switching Problems.** *John Brush,* Allen B. Du Mont Laboratories, Inc.

CP. Recent Advances in Color Television.** *C. J. Hirsch,* Hazeltine Electronics Corporation

2:00 p.m. Transmission and Distribution

51-335—ACO.* A Network Analyzer Analog for Network Field Relations of Overhead Lines. *J. R. Eaton, H. W. Hale, H. J. Oorthuys,* Purdue University

51-336—ACO.* The Mechanism of Corona on A.C. Transmission Lines. *R. Pelissier,* Electricite de France

51-337—ACO.* Generalized Transmission Line Constants. *R. D. Goodrich, Jr.,* Bureau of Reclamation

51-338. An Electric Analog Method for the Direct Determination of Power System Stability Swing Curves. *W. B. Boast,* Iowa State College; *J. D. Rector,* Consolidated-Vultee Aircraft Corporation

51-339. Transposition of High-Voltage Overhead Lines and Elimination of Electrostatic Unbalance to Ground. *E. T. B. Gross,* Illinois Institute of Technology; *A. H. Weston,* Commonwealth Edison Company

2:00 p.m. Heart Fibrillation and Artificial Respiration

CP. Resuscitation in the Surgical Operating Room.** *C. S. Beck,* Lakeside Hospital

CP. Electric Resuscitation of the Ventricular Fibrillating Heart.** *W. B. Kouwenhoven,* The Johns Hopkins University

51-378. Evaluation of Manual Methods of Artificial Respiration. *A. S. Gordon, Max Sadove, Frank Raymon, A. C. Ivy,* University of Illinois

CP. The Ease of Training Personnel in a New Method of Artificial Respiration.** *H. B. Wright,* Cleveland, Ohio

2:00 p.m. Conference on Relay Test Methods

51-371—ACO.* Sensitive Ground Relaying of A. C. Generators. *E. T. B. Gross,* Illinois Institute of Technology

CP. The Use of a Standard Test Manual in Relay Testing.** *J. R. Barnwell,* Tennessee Valley Authority

CP. Comprehensive Testing of Relays and Associated Equipment Using the Transformer Test Set to Simulate Service Conditions.** *J. P. Krug, A. F. Drumpp,* The Detroit Edison Company

CP. Relay Testing Methods with Air Core Reactor Test Set.** *E. L. Jarrett,* Duquesne Light Company

2:00 p.m. Industrial Power Systems

51-356. Equivalent Continuous Current for Groups of Variable Loads. *W. K. Boice,* General Electric Company

51-357—ACO.* Relay Protection of 33 Kv Tie Feeders to a Large Industrial Customer. *W. H. O'Connor,* Consolidated Gas Electric Light and Power Company of Baltimore; *H. D. Ruger,* Bethlehem Steel Company

CP. Electric Power for Jet-Engine Research.** *K. D. Brumbaugh,* National Advisory Committee for Aeronautics, Lewis Flight Propulsion Laboratory

CP. Progress in Electrical Distribution Systems for Bulk Handling Equipment on Lake Docks.** *J. C. Ponstingl,* Westinghouse Electric Corporation

CP. One Industrial Generating System Interconnected to a Public Utility.** *Roy Whaley,* Eli Lilly and Company

Thursday, October 25

9:30 a.m. Transformers

51-340. Overvoltages in Saturable Series Devices. *A. Boyajian, G. Camilli,* General Electric Company

51-374. Evaluation of Butyl Insulation for Outdoor Instrument Transformers. *J. A. McDonnell, H. E. Crabtree,* General Electric Company

51-375. The Closed Core Reactor. *S. Bennon,* Westinghouse Electric Corporation

CP. Proposed Revision of Test Code for Temperature Rise Tests on Transformers.** *Project Group of the Committee on Transformers*

51-81. Insulation Co-ordination and a New Line of Oil Insulated Potential Transformers. *F. J. Vogel,* Illinois Institute of Technology; *D. R. Laib,* Allis-Chalmers Manufacturing Company. Presentation by title only for discussion

51-113. Report on Transformer Magnetizing Current and Its Effect on Relaying and Air Switch Operation. *Subcommittee on Magnetization Characteristics of Transformers.* Presentation by title only for discussion

51-386. The Effects of Coupling-Capacitor-Potential Device Transients on Protective Relay Operation. *Working Group on Transient Characteristics of Capacitance Potential Devices.* Presentation by title only for discussion

9:30 a.m. Basic Sciences

51-340. Overvoltages in Saturable Series Devices. *A. Boyajian, G. Camilli,* General Electric Company

51-342. Synthesis of Paralleled Three-Terminal R-C Networks to Provide Complex Zeros in the Transfer Function. *P. F. Ordung, G. S. Axleby, H. L. Krauss, W. P. Yetter,* Yale University

51-343. The Magnetic Cross Valve. *H. J. McCreary,* Automatic Electric Company. Presentation by title only for discussion

9:30 a.m. Recording and Controlling Instruments

CP. Electronic Recorder with Range and Precision Adequate for the Platinum Resistance Thermometer.** *A. J. Williams, Jr.,* Leeds and Northrup Company

51-344. The Requirements and Design for a Direct Current Null Detector. *F. L. Maltby,* The Bristol Company

CP. Computing Circuits and Devices for Industrial Process Functions.** *A. J. Hornfeck,* Bailey Meter Company

CP. A Time-Proportioning Electronic Thermostat.** *F. A. Ransom,* National Bureau of Standards

51-345—ACO.* Liquid Level Alarm Device. *F. O. Wisman, W. E. Windsor,* Bendix Aviation Corporation

51-381. The Three-Phase Oscilloscope as an Harmonic Analyzer in Power Systems. *E. B. Kurtz, R. H. Burkhardt,* State University of Iowa. Presentation by title only for discussion

9:30 a.m. Radio Communication

51-346. A Short Haul Radio Communication Link, Channelized by Time Division. *E. M. Mortensen, C. B. Young,* The Western Union Telegraph Company

CP. Radio Aids to Navigation on the Great Lakes.** *H. E. De Long*

CP. VHF Communication as Applied to Railroad Operation.** *Ellis Jones, F. H. Menagh*

CP. Radio Communication Speeds Ore Transfer Between Boats and Railroad Cars.** *R. H. Herrick*

9:30 a.m. Steel

CP. Aluminum and Its Relationship to the Electrical Industry.** *H. W. Biskeborn,* Kaiser Aluminum and Chemical Corporation

CP. Inertia Studies for Modern Mill Drives.** *J. F. Sellers, T. B. Montgomery,* Allis-Chalmers Manufacturing Company

51-322. A Heavy Duty Slip Regulator for Steel Mill Service. *W. Schaelchlin, G. E. Mathias,* Westinghouse Electric Corporation. Presentation by title only for discussion

CP. Speed Regulation for Tandem Pipe Mills.** *F. H. Wickline,* National Tube Company

CP. Electric Heating of Steel Strip in Continuous Processes.** *A. R. Ryan,* General Electric Company

2:00 p.m. Feedback Control Systems

51-347—ACO.* Transfer Function for a 2-Phase Induction Servo Motor. *L. O. Brown, Jr.,* University of Illinois

51-348. Analysis of the Drag-Cup A-C Tachometer. *R. H. Frazier,* Massachusetts Institute of Technology

51-324. Sampled-Data Control Systems Studied Through Comparison of Sampling with Amplitude Modulation. *W. K. Linvill,* Massachusetts Institute of Technology

51-271. An Electro-Mechanical A.C. Line Voltage Stabilizer. *D. M. Murray, N. L. Kusters,* National Research Council. Presentation by title only for discussion

2:00 p.m. Symposium on Filter Design

CP. Approximation Methods in Network Theory.** *J. G. Linvill,* Massachusetts Institute of Technology

CP. Lumped Circuit Filter Design.** *F. Hallenbeck,* Bell Telephone Laboratories, Inc.

CP. Coaxial Line Filters.** *J. J. Karakash,* Lehigh University

CP. Rectangular Guide Filters.** *M. D. Brill,* Bell Telephone Laboratories, Inc.

2:00 p.m. Basic Instruments

CP. A General Purpose Electronic Wattmeter.** *D. E. Garrett, F. G. Cole,* General Electric Company

51-323. A Polyphase Thermal Kva Demand Meter. *A. J. Petzinger,* Westinghouse Electric Corporation

51-349—ACO.* Phase-Sensitive-Detector Characteristics. *S. P. Detwiler,* Haller, Raymond and Brown, Inc.

CP. Principles of Converter Design for High Frequency Measurements.** *D. A. Alsberg,* Bell Telephone Laboratories, Inc.

2:00 p.m. Communication Switching Systems

51-321. A New Common Control Crossbar Automatic Telephone System of the Swedish Telephone and Telegraph Administration. *H. F. Rost,* H. F. Rost and Soner

51-350. Relay Counting Chains, Codes and Translations in Dial Pulse Register Circuits. *R. M. M. Oberman,* The Hague, Netherlands

51-351. On the Accuracy of Holding Time Measurements. *Imre Molnar,* Automatic Electric Company

51-352. Investigation of the Selenium Rectifier for Contact Protection. *H. F. Herbig, J. D. Winters,* Federal Telecommunication Laboratories, Inc.

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Friday, October 26

9:30 a.m. Cathodic Protection

CP. Fundamentals of Corrosion.** *R. B. Mears,* United States Steel Company

CP. The Cathodic Protection of Subsurface Structures.** *R. F. Hadley,* Susquehanna Pipeline Company

CP. Low-Energy Measurement Problems in Cathodic Protection.** *H. N. Hayward, R. M. Wainwright,* University of Illinois

CP. Marine Applications of Cathodic Protection Using Graphite Anodes.** *J. P. Oliver,* The Union Carbide and Carbon Corporation

9:30 a.m. Gas Discharge Tubes and Phenomena

51-353. Clean-Up of Helium Gas in an Arc Discharge. *M. J. Reddan, G. F. Rouse,* National Bureau of Standards

51-354. Basis for Dielectric Tests for Rectifier Equipment. *C. C. Herskind,* General Electric Company

51-355. The Design of High Power Vacuum Tubes for Industrial Heating Applications. *H. D. Doolittle,* Machlett Laboratories, Inc. Presentation by title only for discussion

CP. The Plasmatron, A Continuously Controllable Gas-Discharge Tube.** *E. O. Johnson, W. M. Webster,* Radio Corporation of America

CP. A Subminiature Voltage Regulator for Microampere Operation.** *L. R. Landrey,* Sylvania Electric Products, Inc.

9:30 a.m. Magnetic Amplifiers

51-387. Predetermination of Control Characteristics of Half-Wave Self-Saturated Magnetic Amplifiers. *Henry Lehmann,* General Electric Company

51-388. Bibliography of Magnetic Amplifier Devices and the Saturable Reactor Art. *J. G. Miles,* Engineering Research Associates, Inc.

51-389. On the Control of Magnetic Amplifiers. *R. A. Ramey,* Naval Research Laboratory

51-390 Steady-State and Transient Analysis of an Idealized Series-Connected Magnetic Amplifier. *L. A. Pipes,* University of California

50-93. Magnetic Amplifiers of the Balance Detector Type. Their Basic Principles, Characteristics, and Applications. *W. A. Geyger,* United States Naval Ordnance Laboratory. Presentation by title only for discussion

9:30 a.m. Mining

CP. Design Problems of Direct Current Motors for Mining Service.** *J. M. Pokelsek,* The Reliance Electric and Engineering Company

CP. AC vs DC for Underground Mining.** *J. Z. Linsenmeyer, A. G. Owen,* Westinghouse Electric Corporation

CP. Underground Power Distribution.** *R. G. Gehlsen,* Joy Manufacturing Company

CP. Grounding Practices on 480 Volt Portable Distribution Systems.** *R. B. Bennett,* General Electric Company

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(*Continued from page 915*)

eight feet in diameter and weighing a ton or more. All basic processing operations on the raw rubber and the tire building operations will be seen on the trip.

Cadillac Tank Plant (Wednesday, October 24, 1:30 to 4:30 p.m.). This huge plant near the Cleveland Airport, used for the manufacture of bombers during World War II, is now occupied by the Cadillac Motor Car Division of General Motors Corporation for the production of tanks and heavy armoured military vehicles. Currently, the principal product is the *T41E1* Walker Bulldog tank, requiring many spectacularly large and minutely precise machine tools in its manufacture. From the raw materials and parts which flow into the doors of the plant these land battleships are fabricated and assembled, and they roar out other doors to nearby testing grounds. Visitors must carry positive proof of United States citizenship to be admitted for this inspection tour.

Welding positioners like the one shown here help speed production at the Cadillac Tank Plant in Cleveland, to be visited during the meeting. The welder can turn the unfinished turret to any desired position to obtain the best welding conditions for any desired welding pass

Republic Steel Company (Thursday, October 25, 1:30 to 4:30 p.m.). All basic operations of steel making from the coke ovens and blast furnaces to finishing and rolling mills are contained in the plant. One outstanding feature will be inspection of a 98-inch-wide strip mill which was the first of its kind. Aside from the diverse operations in the manufacture of steel, visitors will see many fine electric installations involving large power and precise control.

Lincoln Electric Company (Thursday, October 25, 1:30 to 4:30 p.m.). This is a very recently built, ultramodern manufacturing plant for the production of welding supplies and equipment. Some of its unique features are its windowless construction, straight production lines, visual inventory system, and employee welfare facilities. More than three years of intense planning and design experimentation for most efficient operation were carried out prior to its design and construction. This AIEE trip will be the inaugural inspection of this plant by a group.

ENTERTAINMENT PROGRAM

Social Mixer—Sunday, October 21. A social mixer in the ballroom of the Hotel Cleveland will be held between 3 p.m. and 5 p.m. At this time, the Cleveland Committee will welcome the out-of-town guests who have arrived. Light refreshments will be served (no charge involved).

Stag Banquet—Tuesday, October 23. A stag banquet has been arranged for 6 p.m. in the ballroom. Refreshments will be available in the Red Room adjacent to the ballroom where a sociable cocktail hour can be enjoyed prior to the buffet supper at 7 p.m. After the buffet supper Bill Gordon, WHK's well-known disc jockey, will be the master of ceremonies and will introduce all the acts which have been selected to provide a full evening of entertainment. Tickets at $7.00 each will be available at the ticket desk.

Dinner-Dance—Wednesday, October 24. The Ballroom of the Hotel Cleveland will be the scene of the dinner and dance with dinner at 6 p.m. and dancing from 9 to 12 p.m. A 12-piece orchestra will play for dancing. A 4-piece orchestra will provide music during dinner. Tickets for the dinner-dance are $5.00 and can be obtained at the ticket desk.

Theater Party—Thursday, October 25. The theater party has been arranged at Cleveland's nationally known Euclid-East 77th Street Playhouse where "Anne of a Thousand Days" by Maxwell Anderson will be given. This is a unique show-house. Tickets at $1.35 each are obtainable at the ticket desk in the convention headquarters.

LADIES' PROGRAM

Monday, October 22. This day has been reserved for informal antique inspection parties or for a trip to the Lighting Institute of General Electric's Nela Park. Ladies desiring to participate in either of these functions should contact one of the Cleveland hostesses at the Registration Desk on Monday morning. The antique tours will be made in small informal parties in private cars with a Cleveland lady as hostess. The Nela Park trip to and from Hotel Cleveland will be by bus. This trip will feature, among other things, the latest applications in home lighting on display at the Institute. There will be no charge for either of these trips.

Tuesday, October 23. A get-acquainted tea will be held from 3 to 5 p.m. at the University Club. There will be no charge. On Tuesday at 8 p.m., the ladies are invited to a Helen Slocum Production entitled "Have You Seen the Garden of Eatin'?" This will be held at the Hotel Cleveland.

Wednesday, October 24. Busses will leave Hotel Cleveland at 1 p.m. for a trip to the Cleveland Museum of Art, the Nationality Gardens, and the Historical Society Museum. Light refreshments will be served before returning to the hotel. A charge of one dollar per person will be made for transportation. Wednesday evening the Dinner-Dance will be held.

Thursday, October 25. A luncheon and style show will be held at the Canterbury Golf Club. Busses will leave Hotel Cleveland at 12:15 p.m. A charge of one dollar will be made for transportation. Thursday evening the Theater Party is scheduled.

HOTELS

Rooms are available at Hotel Cleveland, headquarters hotel. Rates are given in the September issue of *Electrical Engineering*, page 823. Rooms may also be reserved in other downtown hotels (Hotels Hollenden, Statler, Carter, and Allerton) by writing directly to the hotel desired.

COMMITTEE CHAIRMEN

The members of the 1951 Fall General Meeting Committee are: D. E. Moat, *General Chairman;* W. R. Hough, *Vice-Chairman;* J. D. Leitch, *Technical Program;* C. J. Beller, *Finance;* V. A. Diggs, *Secretary-Treasurer;* F. E. Harrell, *Non-Technical Activities Co-ordinator;* O. N. Jones, *Member-at-Large;* J. C. Strasbourger, *Vice-President District 2* and *Hotels and Equipment Committee;* C. A. Mann, *Registration;* C. W. Fick, *Trips and Transportation;* R. L. Oetting, *Publicity;* G. R. Canning, *Entertainment;* C. K. Milner, *Hospitality;* Mrs. F. E. Harrell, *Ladies;* and Mrs. V. A. Diggs, *Hostesses.*

Future Aircraft Electrical Requirements to Be Theme of Speakers at AIEE Conference

The AIEE Technical Conference on Aircraft Electrical Applications, sponsored by the Committee on Air Transportation, will be held October 8–10 at the Hollywood Roosevelt Hotel, Hollywood, Calif. "Aircraft Electrical Installation and Environmental Problems" is the general theme of the meeting, and there will be six technical sessions.

A highlight of the conference will be the formal luncheon on Wednesday, October 10, when Commander Harry D. Pickett, Electronic Division, United States Navy, and Lieutenant Colonel James C. Dieffenderfer, Equipment Laboratory, United States Air Force, will be the speakers. Commander Pickett and Colonel Dieffenderfer are the military heads of the Electrical Branches of their respective divisions. Both men are pilots with extensive military experience, and therefore are particularly well suited to address the meeting. Their comments will be directed to future aircraft electrical requirements.

Those going to the AIEE conference will also have the opportunity to attend the annual Society of Automotive Engineers meeting on October 3, 4, and 5 at the Biltmore Hotel and the annual Aircraft Electrical Society (AES) display and dinner October 9 and 10 at the Los Angeles Institute of Aeronautical Sciences Building.

Tentative Technical Program

AIEE Technical Conference on Aircraft Electrical Applications, Hollywood, Calif., October 8–10

Monday, October 8

a.m. Distribution Systems

Impedance Data for 400-Cycle Aircraft Distribution Systems. *G. H. Singer, Jr.*, Boeing Airplane Company

Change in Resistance of Aircraft Current Limiters and Its Effect on Current Division in Networks. *Henry Oman*, Boeing Airplane Company

Instrument Power Isolation as Provided by an Essential Bus System. *H. N. Zwerg*, Lockheed Aircraft Corporation

Intermittent Faults in Aircraft Electrical Systems. *L. R. Larson, M. Trbovich, P. E. Toomire*, Naval Research Laboratory

p.m. Control and Cable

Electrostatic Oscillation in Sensitive Contact Mechanisms. *T. R. Stuelpnagel*, Hughes Aircraft Company

Continuous Current Rating of Bundle Cable for Aircraft. *M. Schach, R. E. Kidwell, Jr.*, Naval Research Laboratory

Flight Simulation of Jet Aircraft Temperature Controls. *F. A. Glassow*, Barber-Coleman Company

Reduced Voltage D-C Motor Controllers for Aircraft. *H. J. Finison, W. C. Anderson*, Armour Research Foundation

Tuesday, October 9

a.m. A-C Generating Systems

Applications of Air-Borne Alternators for Engine Starting. *R. Keith*, Westinghouse Electric Corporation

Exciter Polarity Reversals in Voltage Regulated Aircraft Alternators. *R. P. Judkins, H. M. McConnell*, Westinghouse Electric Corporation

Steady State Characteristics of A-C Generators. *L. R. Larson*, Naval Research Laboratory, *V. C. Holloway*, Westinghouse Electric Corporation

Unit Equipments for Aircraft Electric Power Systems. *H. J. Finison*, Armour Research Foundation

p.m. D-C Generating Systems

Tests of 115-Volt D-C Aircraft Electric Systems. *E. L. Burrough*, Boeing Airplane Company

A Fault Protective System for 30-Volt D-C Aircraft Generators. *R. L. Brown*, Eclipse-Pioneer Division

Effects of Terminal Voltage, Load Current, and Minimum Rotor Speed on the Weight of D-C Aircraft Generators. *D. H. Scott*, Naval Research Laboratory

Short Circuiting Techniques to De-activate a Generator After a Fault. *O. Markowitz, J. W. Pobst*, Naval Air Development Center

Feeder Fault Protection for D-C Aircraft Generators. *W. W. Davis*, Boeing Airplane Company

Wednesday, October 10

a.m. Environment

Rating of Blast Cooled Aircraft Generators. *L. R. Larson, D. H. Scott*, Naval Research Laboratory

Cooling of Electric and Electronic Equipment in High Speed Aircraft. *L. T. Larabee*, Lockheed Aircraft Corporation

Study of Aircraft Electrical Cooling Systems. *Cecil Martin*, Jack and Heintz, Inc.

The Clearance Type Inner Shaft. *I. Kalikow, R. J. LaPlante*, General Electric Company

p.m. Load and Equipment

Aircraft Windshields Heated by Transparent Electrically Conductive Films. *J. W. Ward, Keith Bledsoe*, Boeing Airplane Company

Electric Ignition System for High Altitude Starting of Jet Engines. *J. W. Cross, N. E. Whitchurch, H. E. Sheets*, Goodyear Aircraft Corporation

Light Weight Motor Control for Automatic Pilot. *C. G. Yates*, General Electric Company

The Amplistat on Aircraft. *H. Schirk*, General Electric Company

Electronic Controls as Applied to Alternators and Inverters. *B. N. Starr*, Eicor, Inc.

Admission to the AES display is by invitation only, but invitations to attend one evening will be available at the AIEE registration desk. Exhibits from 35 companies will be included in the display.

The committee members for the conference are: H. F. Rempt, *Chairman;* W. C. Bryant, *Vice-Chairman;* W. L. Berry, *Secretary;* C. E. Gagnier, *Program;* C. R. Moore, *Registration;* W. V. Boughton, *Sessions;* C. S. Milliken, *Financial;* J. R. Harkness, *Arrangements;* and C. J. White, *Publicity.*

Power Development of the Northwest Featured at Pacific General Meeting

The Pacific General Meeting, held in Portland, Oreg., August 20–23, 1951, with headquarters in the Multnomah Hotel, was a well-arranged program of 21 sessions including an opening session and Student technical session. Inspection trips were scheduled to nearby power projects and industries. In the evenings social features were arranged and there were special events for the ladies. An all-time record attendance for Pacific General Meetings of 887 members and guests was established. Friday an all-day trip was taken to Oregon State College at Corvallis, and on the return the Northwest Electrodevelopment Laboratory of the United States Bureau of Mines was visited, as well as the M and M Woodworking Company where the manufacture of plywood was seen from the log to the finished product.

OPENING SESSION

The feature of the opening session was an address, "The Relationship of Hydroelectric Power to Water Resource Development in the Columbia River Basin" by Brigadier General O. E. Walsh, North Pacific Division Engineer, Corps of Engineers. A comprehensive outline of the present and future plans for the development of the entire Columbia River Basin was given by General Walsh, who indicated the initial and ultimate capacities of the several plants and projects. The general objectives of the program were to provide power at low cost and storage space which can be used for flood control and power without conflict. The entire program is integrated with navigation, soil preservation, recreation, and fishing. It is a co-ordinated program with the Bureau of Reclamation and projects are discussed with the public in the region. In this way, the projects will be what the people of the region desire. The address appears in full on pages 861–65 of this issue.

The address of welcome was given by Mayor Dorothy McCollough Lee, who spoke of the importance of the engineering field as it affects national economy and military preparation. In these critical times brought about by the international situation, Mayor Lee emphasized the importance of the scientific mind with the need to be strong in a military and economic way with a knowledge of production and spiritual concepts. The nation was in the spotlight and it must show up well in the eyes of other nations, and with the two great forces at large in the world today, freedom and communism, our thinking and reasons for our way of life must be very straight.

Vice-President J. A. McDonald of the Ninth District addressed the meeting and pledged full support to President McMillan in the tasks ahead. He described the territory of the Ninth District, the Sections, Subsections, and Branches, and drew attention to the rapid rate of growth. In conclusion, he thanked the members of the committees for the excellent arrangements which had been made for the meeting.

Each of the speakers was introduced by C. B. Carpenter, Chairman of the Pacific General Meeting Committee, and at the conclusion of the session he introduced the Chairmen of the several working committees.

LUNCHEON HONORING PRESIDENT MCMILLAN

Before a well-attended luncheon in his honor, President McMillan addressed the gathering on the subject of "Our Heritage from Engineering Education." Engineering education has been a very influential factor in bringing about the industrial development and high standard of living as known here in this country.

President McMillan traced the early development of engineering education in France, England, and Germany, and correlated acceleration or retardation of development in those countries in relation to the system of education in effect. He expressed the view that in the United States we were now facing a critical situation in that the secondary schools have taken the initiative to concentrate on the two-thirds who go into business rather than the one-third who go on to colleges. Where mathematics and sciences are required the situation is particularly serious as 57 per cent of the applicants had to be denied admission to the engineering school and there is a lack of student guidance in this direction. He suggested that members, when returning from the meeting, should look into their secondary school systems and the training of young people.

Electrical World photo

AIEE President McMillan (left) is shown at the Pacific General Meeting with C. B. Carpenter (center), Chairman of the Pacific General Meeting Committee, and Waldo Porter (right), Chairman of the Portland Section

The establishment of engineering education in the United States was traced to West Point in 1812 and Captain Alden Hartridge later founded Norwich Academy in 1819. He referred to Steven van Rensselaer who on November 5, 1824, founded Rensselaer Polytechnic Institute on the principle of "Application of Science to the Common Purposes of Life" which was new to many people at that time. Also, Professor Eaton first established the principle that the students should do the work and not the faculty. Attention was drawn to the work of Dr. Wickenden and the founding of Engineers Council for Professional Development with its method of accrediting schools.

In conclusion, President McMillan cited the number of telephones, tons of steel per capita, and the billions of kilowatt-hours generated in this country which are greatly in excess of anything in foreign countries and this served to emphasize the extent to which our industries have been developed. A comparison between the industrial development of the United States and Great Britain was drawn from an appraisal by Sir Europe Smith in a book, "Critical Importance of Technical Education to Productivity," where it was shown that a man in the United States produces $2^1/_2$ times as much as in Great Britain and that country's lack of industrialization is one of the basic reasons for the economic unbalance between the two countries. We have had a supply of scientifically trained personnel to meet the demands of industry and this has produced the high standard of living which has been attained in this country today.

TECHNICAL SESSIONS

The subject matter for technical sessions ranged throughout the whole gamut of Institute technical activities.

Power: In the field of power, nine sessions were held in which there were papers which dealt with both hydroelectric and steam generation, high-voltage transmission over long distances, grounding effectiveness as verified by stage fault tests, capacitor installations, transformers, switchgear, carrier current and microwave communications, and conductor vibration. In connection with the development and installation of series capacitors, interesting contemporary experience was given by G. Jancke of the Swedish State Power Board and Bror O. N. Hansson, Aktiebolaget Liljeholmens Kabelfabrick, Stockholm. The fundamental difference between series capacitor installations in this country as compared with the Swedish system was explained by Alexander Dovjikov of the Bonneville Power Administration (BPA). Capacitor banks with air-blast spark-gap protection are connected between busses rather than between circuit breakers because the capacitors are needed most when the fault is nearby to compensate for the increase in reactance due to the fault current. With respect to the installation of banks of series capacitors in the middle of the lines in Sweden, Mr. Jancke explained that in that country with most of the generation in the north and the cities far in the south there were five long parallel lines without intermediate switching stations and that it was most economical to install the banks of series capacitors in the middle of the lines. If conditions were the same with networks as in this country, he felt sure that they would solve the problem with the capacitor banks installed at intermediate switching stations as is done in this country.

An interesting discussion also took place in regard to the lowering of the basic impulse insulation level (BIL) on 230-kv systems. H. L. Rorden of BPA expressed belief that past practices had been too conservative but they had gone to 825 kv (BIL) because manufacturers had said that they should not go any lower at this time. He felt that they could go still lower but realized that the manufacturers had a stake in the matter and they did not want to go against the standards.

Industry: Sessions dealt with such problems as protection of electric equipment against corrosion, motor application in the pulp and paper industry, the handling of logs by electric motocylinders (a motor with gear reduction and a crank for turning and positioning logs), and the electric log-carriage drives. Papers in other industrial sessions dealt with such problems as the conversion of the facilities of the Geneva Steel Company to peacetime operation, atomic energy, mining conveyors, pumping, secondary distribution systems, the aluminum industry, cathodic protection of stainless steel buried in the ground, and the economics of cathodic protection.

Communication: Several papers were presented, including one on the nation-wide radio relay connections which was presented by D. I. Cone of the Pacific Telephone and Telegraph Company. Other papers dealt with the *N1* Carrier System by P. G. Edwards of the Bell Telephone Laboratories, Inc., and the Co-ordinated Communication System of the Bonneville Power Administration. An entire session on the subject of carrier current and microwaves dealt with such problems as system relaying, supervisory control, telemetering, and the problems attendant to the communication channels in desert country due to the high ambient temperatures and dust encountered.

Still another session on electric space heating included a discussion of distribution costs, installation and wiring problems, and operating experience and costs of the heat pump installed in the Equitable Building. The latter installation was visited on Thursday on one of the inspection trips.

Science and Electronics: Besides the sessions on carrier current and microwaves and communication for those interested in electronic applications, four sessions were held which dealt with computing devices and methods, instruments and measurements, and electronic power converters.

In the field of aircraft applications and feedback control systems, a session was held in which five papers were presented dealing with carbon-pile voltage regulators, design of permanent magnet alternators, servomechanism characteristics, block diagram networks, and d-c rotating power amplifiers.

STUDENT TECHNICAL SESSION

A Student technical session was held on Tuesday afternoon with Professor O. C. Haycock presiding. The following papers were presented, with first place awarded by the judges to Nymphus M. Murdock:

1. **Thermistor Bridge Pyrheliometer,** *Nymphus M. Murdock,* University of Utah. Presentation by Eldon E. Monson.
2. **Measurement of Sequence Voltages,** *Alfred W. Long,* Oregon State College. Presentation by Robert Short.
3. **Using a Radio Frequency Generator for Induction Heating,** *Fred Emery,* Washington State College. Presentation by Mr. Hansen.
4. **Cable Testing by Inductance Measurements,** *Roy S. Hooper, Jr.,* University of Idaho. Presentation by Duane Taylor.

MEETING OF STUDENT BRANCH COUNSELORS AND CHAIRMEN

A meeting of Student Branch counselors and chairmen was held on Monday evening in which Professor R. M. Saunders, University of California, who was chairman of the District 8 Committee on Student Activities last year, reported on the Student Branch counselors' meeting held in Toronto. Subsequently, the meeting convened and the Student Branch counselors of the Eighth and Ninth Districts met separately for a discussion of the operation of the Branches in the Districts.

Electrical World photo

F. O. McMillan, President of the Institute, is talking with, left to right, G. Jancke, Swedish State Power Board; Bror O. N. Hansson, of the Aktiebolaget Liljeholmens Kabelfabrick of Stockholm; and P. L. Bellaschi, Consulting Engineer

INSPECTION TRIPS

Besides the all-day trip on Friday to Oregon State College, United States Department of the Interior, Bureau of Mines, and M and M Woodworking Company, trips were taken on the several days during the meeting to J. D. Ross Substation, McNary Dam, Aluminum Company of America, Crown Zellerbach Corporation, Bonneville Dam and Powerhouse, Weyerhaeuser Timber Company, the 230-kv series capacitors' installation at Chehalis Substation of BPA, the Equitable Building, and the Yale and Merwin Hydroelectric Development of the Pacific Power and Light Company. Steam plants and substations of the Portland General Electric and Pacific Power and Light Company also were visited on arrangement.

SOCIAL EVENTS

For the ladies on Monday afternoon, there was a reception in honor of Mrs. McMillan and the wives of the Board of Directors at the Portland Art Museum. On Tuesday evening, there was a reception for President McMillan followed by colored scenic movies of Oregon and Washington.

Each day the ladies were kept busy with a specially arranged series of tours and get-togethers. A trip was taken up the Columbia River Highway for a visit to the Sanctuary of Our Sorrowful Mother with its beautiful monastery gardens, and to Multnomah Falls. On Wednesday, there was a luncheon at the Columbia Edgewater County Club followed by entertainment and prizes. On Thursday, an all-day trip was taken to Timberline Lodge and Mt. Hood.

BANQUET AND DANCE

A banquet was held in the Grand Ballroom of the Multnomah Hotel on Wednesday evening preceded by a social hour. After the banquet, there was entertainment of a musical and comic variety which was later followed by dancing.

GOLF TOURNAMENT

Sports prizes were presented by J. A. Tudor and the Annual Golf Tournament for the J. B. Fisken Cup was played at the Alderwood Country Club. The winner of the cup was R. L. Lemman with a low net of 65 and also the winner of the low net on the second flight. The second winner was W. T. Hammon with a low gross on the second flight of 67 and E. W. Rockwell was the winner of the low gross on the first flight with a 66. O. A. Gustafson won the low net on the first flight.

COMMITTEES

Members of the Pacific General Meeting Committee which made the arrangements were as follows: C. B. Carpenter, *Chairman;* M. M. Ewell, *Vice-Chairman;* D. A. Riechel, *Secretary;* A. O. Mangold, *Treasurer;* Waldo E. Enns, *Technical Programs;* D. L. Brown, *Registration;* C. L. Brown, *Hotels;* A. O. Mangold, *Finance;* O. A. Demuth, *Inspection Trips;* M. G. Poland, *Transportation;* M. D. Duffy, *Entertainment;* R. B. Temple, *Students;* W. Porter, *Sports;* Mrs. M. M. Ewell, *Ladies;* R. R. Bracchi, *Publicity.*

Regular Meeting of AIEE Board of Directors Held in Toronto, Canada

A regular meeting of the Board of Directors of the Institute was held in the Royal York Hotel, Toronto, Ontario, Canada, on June 28, 1951.

The minutes of the meeting of the Board of Directors held in Miami Beach, Florida, on April 12, 1951, were approved.

The following actions of the Executive Committee on membership applications, upon recommendation of the Board of Examiners, were reported and confirmed: As of May 25, 1951: 14 applicants transferred to the grade of Fellow; 39 applicants transferred, and 71 applicants elected to grade of Member; 2 Members reinstated, and 4 Members re-elected; 186 applicants elected to grade of Associate, and 13 Associates re-elected; 519 Student members elected to grade of Associate; 195 Student members enrolled.

Recommendations adopted by the Board of Examiners at meetings on April 19, May 17, and June 21, 1951, were reported and approved. The following actions were taken upon recommendation of the Board of Examiners: 27 applicants were transferred to the grade of Fellow; 77 applicants were transferred, 35 applicants were elected, and 1 applicant was re-elected to the grade of Member; 186 applicants were elected, and 3 were re-elected to grade of Associate; 193 Student members whose terms expired April 30, 1951, were elected Associates; 220 Student members were enrolled.

The Membership Committee was requested to submit recommendations regarding a badge for the grade of Affiliate which was recently established.

FINANCES

The Board approved expenditures reported by Chairman W. J. Barrett of the Finance Committee, as follows: April, $74,389.53; May, $83,620.75; and June, $84,674.40.

Mr. Barrett reported that, to June 21, 77.5 per cent of the estimated income for the appropriation year had been received and that for the corresponding period of last year the income had been 76.5 per cent of the actual income for the year; for the nine months ending June 30, expenditures were 73.7 per cent of the estimated expenditures for the year, as compared with expenditures for the same period last year of 76.1 per cent of total expenditures during the year ended September 30, 1950.

Mr. Barrett mentioned the excess of income over expense of $15,746.46 shown by the Haskins and Sells Report for the fiscal year ended April 30, 1951, and pointed out that if the cost of installing the headquarters air-conditioning equipment had originally been paid from the Reserve Capital Fund, instead of being paid first from the operating funds, with the charge later transferred, the 1949–50 report would have shown an excess of income over expenditures of $3,691.77, and the corresponding item in the 1950–51 report would have been $11,294.07.

Because of a larger number of accepted technical papers than expected, a further increase of $3,000 was made in the appropriation for preprints.

The Finance Committee reported that in some cases prizes have been awarded to authors who were not Members or Student members of the Institute. The Committee on Award of Institute Prizes was requested to send out a special letter calling the attention of all District, Section, and Branch officers to the great desirability of adhering to the rules which restrict the award of prizes to Members and Student members of the Institute.

Upon recommendation of the Publication Committee, an appropriation of $750 was made for a business-machine analysis of the replies to the questionnaire on technical division publications sent to the membership in the spring.

APPOINTMENTS

Secretary H. H. Henline was reappointed Secretary of the Institute for the administrative year beginning August 1, 1951.

F. M. Farmer was reappointed a member of the Board of Trustees of the Retirement System of the AIEE for a term of 4 years.

Dr. D. D. Ewing was appointed a Volta Scholarship Trustee for a term of 6 years.

Dr. W. B. Kouwenhoven was nominated for reappointment as a representative on the National Research Council for a term of 2 years.

N. L. Freeman was designated to represent the Institute at the annual banquet of the National Council of State Boards of Engineering Examiners, in Boston, Mass., October 23.

Mohamad Hussain Khalid (M '50), Executive Engineer, Construction Division, Electricity Dept., NWFP, Nowshera, Pakistan, was appointed Local Honorary Secretary for Pakistan for a 2-year term ending July 31, 1953.

COMMITTEE ON PLANNING AND CO-ORDINATION

Upon recommendation of the Committee on Planning and Co-ordination, these meetings were authorized:

Winter General, New York, January 18–22, 1954

North Eastern District, Schenectady, N.Y., May 5–7, 1954

The committee also recommended and the Board approved the establishment of an inactive membership status for members in the armed forces (*EE, Sept '51, p 824*).

STANDARDS COMMITTEE

The following appointments of representatives were reported by the Standards Committee:

Sectional Committee *Z10*, "Letter Symbols": C. C. Chambers, representative.

Sectional Committee *Y15*, "Preferred Practice for the Presentation of Graphs, Charts, and Other Technical Illustrations": G. C. Baxter Rowe, representative.

Sectional Committee *Z32*, "Graphical Symbols and Designations": L. E. Markle, representative; M. D. Ross, alternate.

Sectional Committee *Z54*, "Safety Code for the Industrial Use of X-Rays": J. T. Wilson, representative (subject to his election to AIEE membership).

The Standards Committee approved the following Standards:

Revision of present AIEE *20* and *20A*: "Air Circuit Breakers" and "Low Voltage Air Circuit Breakers" respectively.

Graphical Symbols for Single (One) Line Electrical Engineering Diagrams.

American Standard Test Code for Apparatus Noise Measurement, *Z24.7*, to supersede AIEE *520* on same subject.

The Standards Committee approved the proposal of American Standards Association to issue a Standards Medal (referred to the Standards Committee with power by the Board of Directors at their meeting on April 12.) The Committee also approved the joint AIEE-Institute of Radio Engineers proposal to the International Consultative Committee on Radio (CCIR) to consider the recommendation of the AIEE Subcommittee on Standard Frequency Bands and Designations as a revision of the present international standard for frequency bands and designations.

SECTIONS COMMITTEE

Upon recommendation of the Sections Committee, the following actions were taken:

Authorized the establishment of a Central Illinois Section by the combination of the Urbana Section and the Sangamon Subsection of the Illinois Valley Section.

Authorized the establishment of a Nashville Section from the former Nashville Subsection of the Memphis Section, with certain counties from the territory of the East Tennessee Section in addition to those in the Memphis Section territory which had been assigned to the Subsection.

Authorized the establishment of a Tri-State Section from the former Tri-State Division of the West Virginia Section, with a territory composed of certain counties in the states of Kentucky, Ohio, and West Virginia, the entire Section to be in District 2.

Authorized the establishment of a Mississippi Section from the former Jackson Subsection of the New Orleans Section.

Changed the name of the Western Virginia Section to Virginia Mountain Section.

COMMITTEE ON CONSTITUTION AND BYLAWS

Because of the adoption of the proposed amendments to the Constitution which were submitted to the membership in the spring, the renumbering of the sections of the Constitution as recommended by the committee was approved.

As recommended by the committee, in line with previous general approval by the Board of Directors, Section 94 of the Bylaws was amended to relieve the President of serving on the John Fritz Medal Board of Award, and to make the surviving junior past president a representative of the AIEE on that board as of October 1.

Section 32 of the Bylaws, providing for a co-ordinating committee in each District, was deleted in accordance with a recommendation of the 1950 Conference of Vice-Presidents and District Secretaries and previous approval in principle by the Board.

GENERAL

The annual Report of the Board of Directors for the fiscal year which ended April 30, 1951, was approved (*EE, Aug '51, pp 724–50*)

The Board voted to support a request by the American Society of Civil Engineers (ASCE) that a commemorative postage stamp be dedicated to the Centennial of the ASCE in 1952.

Plans for AIEE participation in the Centennial of Engineering in 1952 were presented, as follows:

Wednesday
Sept. 10—A.M. Industry Division
P.M. General Applications Division
Thursday
Sept. 11—A.M. Power Division
P.M. Power Division
Friday
Sept. 12—A.M. Communication Division
P.M. Science and Electronics Division

The Board of Directors voted to authorize the Engineers Joint Council (EJC) to approve the proposed constitution of the Union of Pan American Engineering Associations (UPADI) as a document under which UPADI will operate until the next convention, approved the nomination of EJC President J. M. Todd as the first UPADI Director from the United States, and approved the nomination of S. L. Tyler, Secretary of the American Institute of Chemical Engineers, as the EJC member of the permanent UPADI Constitution and Bylaws Committee.

Past President J. F. Fairman reported upon the replies from Sections and Subsections regarding proposed types of unity organizations for the engineering profession. The Board expressed its thanks to him for his hard work as AIEE representative on the Exploratory Group during the past year. Upon his recommendation, Titus G. LeClair was appointed AIEE representative on that group effective June 29, 1951.

Because of his election as President, Prof. F. O. McMillan resigned as Director, and Arthur H. Frampton was elected a Director for the remainder of the term ending July 31, 1952.

The President was requested to express to District 10, the Toronto Section, and the Summer General Meeting Committee thanks and appreciation on the part of the Board for a fine meeting.

Members of the Board whose terms were to expire July 31, 1951, expressed the great satisfaction they had received from their association with the other members.

Various other matters were considered.

Present at the meeting were: *President* T. G. LeClair; *Past President* J. F. Fairman; *Vice-Presidents* W. C. DuVall, A. H. Frampton, H. R. Fritz, R. A. Hopkins, J. A. McDonald, J. R. North, C. S. Purnell, W. J. Seeley, J. G. Tarboux, C. G. Veinott; *Directors* W. J. Barrett, W. L. Everitt, C. W. Fick, N. B. Hinson, M. D. Hooven, F. O. McMillan, A. C. Monteith, Elgin B. Robertson, H. J. Scholz, Victor Siegfried; *Treasurer* W. I. Slichter; *Secretary* H. H. Henline; By invitation: incoming Vice-Presidents J. D. Harper, F. W. Norris, J. C. Strasbourger, W. R. Way; incoming Directors R. F. Danner, D. D. Ewing.

Program of Fractional Horsepower Motor Conference Released

The AIEE Technical Conference on Fractional Horsepower Motor Applications to Refrigeration Equipment and Pumps will be held in the Dayton Biltmore Hotel, Dayton, Ohio, October 11 and 12. The conference is being sponsored by the Fractional Horsepower and Single-Phase Subcommittee of the Rotating Machinery Committee in conjunction with the Domestic Appliances Subcommittee and the Dayton Section. Three papers are scheduled on the application of motors to refrigeration and air-conditioning equipment, and five papers on motor applications to various types of pumps.

In addition, papers on starting relays for refrigeration motors, automatic defrost controls, low temperature insulation characteristics, and Fiberglas in the wire and cable industry will complete the program.

A special feature of the conference is a trip through the Frigidaire Division of the General Motors Corporation, planned for the evening of October 11.

The conference program schedule is as follows:

Thursday, October 11

9:30 a.m.

Application of Motors to Household Refrigeration Compressors. *L. C. Packer*, Westinghouse Electric Corporation

Design of Refrigeration Automatic Defrost Controls. *Robert Ramey*, Ranco Inc.

NEMA Standards for Hermetic and Belted Refrigeration Motors. *T.E.M. Carville*, Westinghouse Electric Corporation

2:00 p.m.

Motor Application Problems on Air Conditioning Equipment. *W. L. McGrath*, Carrier Corporation

Fiberglas in the Wire and Cable Industry. *W. K. Lydic*, Owens-Corning Fiberglas Corporation

Low Temperature Insulation Characteristics. *Vincent DiMaio*, Owens-Corning Fiberglas Corporation

8:00 p.m.

Inspection trip through the Frigidaire Division, General Motors Corporation

Friday, October 12

9:30 a.m.

The Application of Motors to Pumps. *R. A. Fuller*, General Electric Company

Application of Motors to Jet Type Pumps. *W. J. Conery*, F. E. Myers and Brothers Company

Application of Motors to Gasoline Pumps. *G. Wright*, Tokheim Oil Tank and Pump Company

2:00 p.m.

Fractional Horsepower Motor Application to Sump Pumps for Domestic Service. *J. C. Dennis*, Penberthy Injector Company

Application of Single Phase Fractional Horsepower Motors to Reciprocating Pumps. *A. G. Horvath*, Master Electric Company

For information regarding registration and hotel accommodations, write to D. C. Breeding, Frigidaire Division, General Motors Corporation, Dayton, Ohio.

Joint AIEE–IRE Computer Conference to Be Held in Dec.

A joint AIEE–Institute of Radio Engineers (IRE) Computer Conference for a discussion of the principal operating digital computers will be held in Philadelphia, Pa., December 10–12, 1951. This will be the first meeting held specifically to review accomplishments in the relatively new field of large-scale digital computer engineering. Selection of the conference location has been influenced by the large number of computer manufacturers and users in the area.

Conference meetings will be held Monday and Wednesday, December 10 and 12, in the Benjamin Franklin Hotel and on Tuesday in the auditorium in the Edison Building. A luncheon is scheduled for Wednesday noon at the Benjamin Franklin and inspection trips to local computer manufacturing centers are planned for Monday and Wednesday. Arrangements for the meeting will be completed by a committee under the chairmanship of John C. McPherson of the International Business Machines Corporation; members of the Computing Devices Committees of both sponsoring societies are on the conference committee, as well as invited members of the Association for Computing Machinery.

The committee has chosen as its aim in preparing the conference agenda the discussion of the useful results obtainable from the present large-scale digital computers. It is hoped that an indication of the shortcomings revealed by working on actual problems will be an aid in showing the direction along which improvements should be made.

To accomplish this aim, papers from computing groups which have realized an operating system have been invited. Parallel sessions will be avoided, and sufficient time will be allotted to each paper so that a rather complete treatment, including discussion, can be made. The keynote of the conference is to be evaluation of achievements. Future possibilities will be de-emphasized so that engineers may discover what has been accomplished so far in this rapidly expanding field.

AIEE Officers to Be Nominated for 1952 Election

For the nomination of officers to be voted upon in the spring of 1952, the AIEE Nominating Committee will meet in New York, N. Y., in January 1952. The officers to be elected are: a president, a treasurer, three directors, and five vice-presidents, one from each of the odd-numbered geographical Districts. Fellows only are eligible for the office of president, and Members and Fellows for the offices of vice-president, directors, and treasurer.

To guide this committee in performing its constituted task, suggestions from the membership are, of course, highly desirable. To be available for consideration of the committee, all suggestions must be received by the secretary of the committee at Institute headquarters not later than December 15, 1951.

In accordance with the provisions in the constitution and bylaws, quoted in the following paragraphs, actions relating to the organization of the Nominating Committee are now under way.

Constitution

29. There shall be constituted each year a Nominating Committee consisting of one representative of each geographical District, elected by its executive committee, and other members chosen by and from the Board of Directors not exceeding in number the number of geographical Districts; all to be selected when and as provided in the bylaws. The Secretary of the Institute shall be the secretary of the Nominating Committee, without voting power.

30. The executive committee of each geographical District shall act as a nominating committee of the candidate for election as vice-president of that District, or for filling a vacancy in such office for an unexpired term, whenever a vacancy occurs.

31. The Nominating Committee shall receive such suggestions and proposals as any member or group of members may desire to offer, such suggestions being sent to the secretary of the committee.

The Nominating Committee shall name, on or before January 31 of each year, one or more candidates for president, treasurer, and the proper number of directors, and shall include in its ticket such candidates for vice-presidents as have been named by the nominating committees of the respective geographical Districts, if received by the Nominating Committee when and as provided in the bylaws; otherwise the Nominating Committee shall nominate one or more candidates for vice-president(s) from the District(s) concerned.

Bylaws

Sec. 21. During September of each year, the Secretary of the Nominating Committee shall notify the chairman of the executive committee of each geographical District that by December 15 of that year the executive committee of each district must select a member of that District to serve as a member of the Nominating Committee and shall, by December 15, notify the Secretary of the Nominating Committee of the name of the member selected.

During September of each year, the Secretary of the Nominating Committee shall notify the chairman of the executive committee of each geographical District in which there is or will be during the year a vacancy in the office of vice-president that by December fifteenth of that year a nomination for a vice-president from that District, made by the District executive committee, must be in the hands of the Secretary of the Nominating Committee.

Between October first and December fifteenth of each year, the Board of Directors shall choose five of its members to serve on the Nominating Committee and shall notify the secretary of that committee of the names so selected and shall also notify the five members selected.

The Secretary of the Nominating Committee shall give the fifteen members so selected not less than ten days' notice of the first meeting of the committee, which shall be held not later than January thirty-first. At this meeting, the committee shall elect a chairman and shall proceed to make up a ticket of nominees for the offices to be filled at the next election. To insure that full consideration be given to all suggestions from the general membership, they must be in the hands of the secretary of the committee by December fifteenth. The nominations as made by the Nominating Committee shall be published in the March issue of *Electrical Engineering*, or otherwise mailed to the Institute membership not later than the first week in March.

Independent nominations may be made in accordance with provisions in article VI, section 32, of the constitution and section 22 of the bylaws, which are quoted below:

Constitution

32. Independent nominations may be made by a petition of twenty-five (25) or more corporate members sent to the Secretary when and as provided in the bylaws; such petitions for the nomination of vice-presidents shall be signed only by members within the District concerned.

Bylaws

Sec. 22. Petitions proposing the names of candidates as independent nominations for the various offices to be filled at the ensuing election, in accordance with article VI, section 32 (Constitution), must be received by the secretary of the Nominating Committee not later than March 25 of each year, to be placed before that committee for the inclusion in the ballot of such candidates as are eligible.

On the ballot prepared by the Nominating Committee in accordance with article VI of the Constitution and sent by the Secretary to all qualified voters on or before April 15 of each year, the names of the candidates shall be grouped alphabetically under the name of the office for which each is a candidate.

(*Signed*) H. H. Henline
Secretary

Exploratory Group to Consider Further Unity of Profession

At the June meeting of the AIEE Board of Directors in Toronto, Canada, Mr. James F. Fairman presented a progress report on the subject of unity in the engineering profession and the work of the Exploratory Group to Consider Means of Further Unity.

At this meeting, Mr. Fairman stated that, in common with several other societies, AIEE has asked the various Sections to review the report on the four plans for organization and to express their preference.

The summary of the preferences expressed is contained in the following tabulation:

	Sections
For Plan A	12
For Plan B	0
For Plan C	32½
For Plan D	10½
For none	3
No preference	2
Total	60

In commenting on the report, Mr. Fairman indicated that some slight discount should be taken in the preference for Plan C as this plan is close to the one that AIEE previously showed preference for in the voting in 1947. Nevertheless, it does indicate that the Institute membership has a tendency to prefer the compromise plan which utilizes much of the benefits of existing organizations with the understanding that any reasonable modification would be acceptable.

The Board of Directors took no formal action in order that its representative to the Exploratory Conference be free to proceed with these plans or any modification which will accomplish the result of greater unity.

The Directors also accepted with thanks the resignation of Mr. Fairman as its representative to the Exploratory Conference and selected Dr. T. G. LeClair as his successor. Dr. LeClair originally had the assignment as the Institute's representative, but relinquished this during the term of his AIEE presidency.

Engineers' Committee on Student Guidance. S. P. Shackleton has been elected Chairman of the New York Engineers' Committee on Student Guidance. The committee operates under the auspices of the Engineers' Council for Professional Development (ECPD) and is composed of 100 representatives of the New York Sections of the major engineering societies. It has functioned for 15 years, counseling and guiding high-school students and faculties on engineering education and on opportunities in the engineering field. Its services have been offered to all high schools and preparatory schools in New York City and suburbs. Mr. Shackleton has been Chairman of the AIEE subcommittee and treasurer and liaison secretary of the larger group. As Chairman of the New York Committee he will serve on the national guidance committee of ECPD.

COMMITTEE ACTIVITIES

Editor's Note: This department has been created for the convenience of the various AIEE technical committees and will include brief news reports of committee activities. Items for this department, which should be as short as possible, should be forwarded to R. S. Gardner at AIEE Headquarters, 33 West 39th Street, New York 18, N. Y.

Industry Division

Committee on Electric Welding (*C. N. Clark, Chairman; E. J. Limpel, Vice-Chairman; J. F. Deffenbaugh, Secretary*). At the August 8th meeting of the Committee on Electric Welding it was decided to recommend the establishment of a subcommittee to study the applications of instruments to resistance welding, and that such a subcommittee have 12 to 15 members from the Committee on Electric Welding with representatives from the American Welding Society, the National Electrical Manufacturers Association, and the AIEE Committee on Instruments and Measurements.

A third conference on Electric Welding will be held at the Rackham Memorial Building, Detroit, Mich., on April 16, 17, and 18, 1952. The conference is sponsored by the AIEE Committee on Electric Welding, in co-operation with the Michigan Section AIEE, the American Welding Society, and the Industrial Electrical Engineers' Society of Detroit. The program will include seven technical sessions and a demonstration of electric welding equipment. Conference Chairman is C. N. Clark, Duquesne Light Company, Pittsburgh, Pa.

Committee on General Industry Applications (*V. O. Johnson, Chairman; F. D. Snyder, Vice-Chairman; E. M. Hays, Secretary*) An interesting session of discussion in the relatively new field of "Electronic Equipment in Industry" will be planned for the next Winter General Meeting. Discussion will center around advantages of and problems connected with the use of electronic equipment in industry.

Many conferences of special interest are also being planned by the subcommittees. A special conference on machine tools will be held in Rockford, Ill., on November 14, 15, and 16 of this year. Its predecessor last year, held in Worcester, Mass., was well attended by members of the machine tool industry.

Conferences are also being planned for this fall dealing with the pulp and paper industry, the rubber and plastics industry, and the textile industry. The Textile Industry Subcommittee staged two very successful meetings in April, one in Philadelphia and one at the Georgia School of Technology in Atlanta.

This Committee is fortunate in having a very active group on the west coast which can be termed a West Coast Subcommittee. This group sponsored a session at the Pacific General Meeting in Portland, Oregon, on Tuesday, August 21. Subjects on papers dealt with the very active pulp, paper, and lumber industries in the Northwest.

Power Division

Committee on Switchgear (*H. V. Nye, Chairman; R. L. Webb, Vice-Chairman; J. M. Geiger, Secretary*). The Committee on Switchgear has under consideration at this time revisions of the following standards:

Number 20—Low Voltage Air Circuit Breakers
Number 22—Air Switches, Insulator Units and Bus Supports
Number 25—Fuses above 600 Volts
Number 27—Power Switchgear Assemblies

The first named standard, Number 20, has been approved by the Standards Committee and will be issued shortly. The others are now close to final form and probably will be submitted for approval very soon. On the completion of this work, it is felt that the AIEE switchgear standards will be in as satisfactory form as is possible for the present.

Other subjects than standards are being given attention by appropriate subcommittees. One of these is a study of operating temperatures in outdoor switchgear with a consideration of precautions to be taken in making applications of this widely used type of equipment. The Power Circuit Breaker Subcommittee in particular has developed a great deal of interest in the proper method of rating circuit breakers. Plans are being made to arrange for a session at the Winter General Meeting, at which some papers will be presented for discussion of this timely subject.

Committee on Transformers. A working group of the Committee on Transformers presents the following statement representing the opinion of last year's committee, of which J. B. Hodtum was chairman.

"It is the opinion of this Committee that at the present time, limits of insulation power factor can not be set for factory tests of transformers. It is suggested that the users conduct tests when first placing the transformers in service and that records be maintained of subsequent tests. The trend of the curve plotted from measurements is to be used to ascertain the condition of the transformers." (From the May 24, 1951, minutes of the Committee on Transformers of the AIEE.)

Science and Electronics Division

Committee on Computing Devices (*W. H. MacWilliams, Chairman; V. C. McPherson, Vice-Chairman; F. J. Maginniss, Secretary*). A bibliography of published literature on computers is being prepared jointly with the Electronic Computers Committee of the Institute of Radio Engineers. A draft of two of the three sections is being circulated for review and preparation of thumbnail abstracts. The bibliography will be published at cost by the AIEE, probably in this calender year.

Committee on Magnetic Amplifiers (*E. L. Harder, Chairman; E. V. Weir, Secretary*). Magnetic amplifier work in the AIEE was organized as a subcommittee of the Electronics Committee in the fall of 1948. In two and one-half years it has grown to a full Institute committee, operating with nine subcommittees, and has produced a progress report covering the initial work on definitions, standards, and application information. It was changed from a subcommittee of the Electronics Committee to a full technical committee in the month of January 1951.

Through the committee discussions and the progress report on definitions and standards, much of the loose talk regarding magnetic-amplifier performance has been eliminated and a majority of the papers and articles are now appearing with information presented in a mutually understandable form. This marks the end of one phase of the committee work. The activity is quite firmly established in the AIEE and is providing the desired interchange of ideas and progress in standardization.

The principal subcommittees now having active assignments are those on Definitions, Ratings, Applications, Test Code, Materials, and Non-Linear Circuit Theory arising particularly in magnetic amplifiers. The committee is also sponsoring some bibliography work.

AIEE Section and Student Branch Meetings—1950–1951

Table I. Section Membership and Meetings During Year Ending April 30, 1951

Section	AIEE Members August 1950	Number of Meetings	Total Number of Meetings
Akron	137	9	9
Alabama	276	10	
Subsection: Mobile-Pensacola		10	20
Arizona	195	11	
Group: Technical		11	22
Arkansas	112	9	
Group: Technical		7	
Subsection: Northwest Arkansas		8	24
Arrowhead	50	9	9
Beaumont	85	9	
Group: Technical Discussion		4	13
Boston	924	8	
Groups: Basic Sciences		2	
Distribution		2	
Electronics		2	
Industrial Power Applications		2	
Instruments and Measurements		2	
Insulation		3	
Land Transportation		1	
Power Generation		2	
Transmission		2	
Wire Communications		2	
Subsection: New Hampshire		4	32
Canton	95	11	11
Central Indiana	313	10	10
Chicago	1,844	4	
Groups: Basic Sciences		3	
Communications		4	
Electronics		5	
Industrial		5	
Power		5	26
Cincinnati	266	14	
Group: Technical		4	18
Cleveland	810	8	
Groups: Basic Science		4	
Electrical Construction		4	
Instruments and Measurements		4	
Motors and Controls		6	
Power Generation and Distribution		5	31
Columbus	152	10	
Subsection: Zanesville		11	21
Connecticut	536	8	
Group: Technical		16	24
Dayton	385	10	
Groups: Aeronautics		2	
Electronics		3	
Motors and Control		3	
Power		3	
Subsection: Lima		8	29
Denver	442	11	
Groups: Communications		5	
Electrical Equipment		3	
Power System		4	
Subsections: Black Hills		4	
Casper (Wyo.)		6	33
East Tennessee	333	13	
Group: Knoxville Technical		6	19
Erie	167	14	
Subsection: Ridgway		8	22
Florida	161	4	
Subsection: Tampa		3	7
Fort Wayne	139	9	9
Georgia	255	10	
Subsection: Savannah		7	17
Houston	290	10	
Groups: Communications		1	
Industrial Applications		3	
Subsection: Freeport		5	19
Illinois Valley	146	12	
Group: Technical		5	
Subsection: Sangamon		8	25
Iowa	202	6	
Subsection: Quad-Cities		7	13
Ithaca	213	9	
Group: Technical		7	
Subsection: Binghamton Area		6	
Binghamton Area Technical Group		5	27
Kansas City	299	15	
Groups: Calculating Board		1	
Circuit Interrupting Devices		8	
Generator Voltage Regulators		8	
Transmission Lines		7	39
Lehigh Valley	373	11	11
Los Angeles	1,471	9	
Groups: Aircraft		8	
Electronics		7	
Power		7	
Subsection: Boulder City		9	40
Louisville	138	12	12
Lynn	298	19	19
Madison	88	8	8
Mansfield	82	8	
Group: Electronics		1	9
Maryland	674	9	
Groups: Communications		3	
Industrial Electronics		2	
Power		4	
Subsections: Eastern Shore		8	
Lancaster-York		6	32
Memphis	171	10	
Subsection: Nashville		8	18
Mexico	213	—	—
Miami	114	12	12
Michigan	845	7	
Groups: Electric Welding		3	
Electronics		4	
Industrial Power		2	
Instruments and Measurements		2	
Round Table		5	
Subsection: West Michigan		5	28
Milwaukee	785	11	
Groups: Basic Science		5	
Electric Machinery		3	
Electronics		7	
Power Application and Control		2	
Transmission and Distribution		3	
Subsections: Fox River Valley		8	
Racine-Kenosha		2	41
Minnesota	352	16	
Subsection: Red River Valley		9	25
Montana	123	4	
Subsection: Billings		11	15
Montreal	324	15	
Subsection: St. Maurice Valley		8	23
Nebraska	140	8	8
New Mexico-West Texas	193	14	
Group: Technical		6	
Subsection: Albuquerque		5	25
New Orleans	309	10	
Group: Technical		2	
Subsections: Baton Rouge		7	
Jackson (Miss.)		8	
Lake Charles		8	35

Table I (continued). Section Membership and Meetings During Year Ending April 30, 1951

Section	AIEE Members August 1950	Number of Meetings	Total Number of Meetings
New York	5,245	3	
Groups: Basic Science		4	
Communication		11	
Illumination		5	
Power and Industrial		13	
Transportation		5	
Subsections: Hudson Valley		6	
New Jersey		5	
Joint Meeting: Communication and New Jersey		1	53
Niagara Frontier	278	13	13
Niagara International	121	17	17
North Carolina	265	2	
Subsections: Charlotte		9	
Mid-State		4	15
Northeastern Michigan	105	9	9
Northern New Mexico (Established 1–25–51)		2	2
North Texas	500	11	
Groups: Distribution Practices		1	
Electronics		1	
Industrial Practices		2	
Subsections: Central Texas		9	
Fort Worth		6	
West Central Texas		8	38
Oak Ridge	117	8	
Group: Technical		2	10
Oklahoma City	208	8	
Groups: Communications		1	
Electronics		1	10
Ottawa	68	15	15
Panhandle Plains	171	10	
Group: Industrial Practices		2	12
Philadelphia	1,555	13	
Groups: Basic Sciences		3	
Communications		4	
Electronics		3	
Industrial Practices		3	
Instruments and Measurements		3	
Power Systems		3	
Subsection: Wilmington		12	44
Pittsburgh	1,202	16	
Subsections: Centre County		6	
Johnstown		11	33
Pittsfield	326	15	
Group: Discussion		6	21
Portland	534	23	23
Providence	165	8	8
Richland	104	14	14
Rochester	234	23	
Groups: Communication		1	
Power		1	25
Rock River	101	9	9
Sacramento	96	7	7
St. Louis	609	10	
Groups: Electronics		8	
Industrial Apparatus		9	
Industrial Power Practices		8	35
San Diego	159	11	
Group: Technical		3	14
San Francisco	1,251	32	
Subsections: Eureka		6	
Fresno		4	
Hawaii		2	
Sacramento		2	
San Jose		9	
Shasta		8	63
Schenectady	1,015	18	18
Seattle	524	12	
Groups: Basic Science		4	
Electronics and Communication		3	
Power		7	
Transportation		4	
Subsection: Tacoma		9	39
Sharon	201	12	12
Shreveport	96	9	9
South Bend	117	9	9
South Carolina	147	1	
Subsection: Columbia		7	8
South Texas	205	10	
Subsection: Corpus Christi		9	19
Spokane	154	9	9
Springfield	95	7	
Group: Technical		2	9
Syracuse	252	10	
Subsection: St. Lawrence International		7	17
Toledo	129	9	
Groups: Motors and Control		2	
Power Systems		2	13
Toronto	628	15	
Groups: Communications		3	
Discussion		12	
Subsection: Hamilton		8	
Joint Meeting: Section and Hamilton Subsection		1	39
Tulsa	160	9	
Group: Technical		14	23
Urbana	93	5	5
Utah	137	11	
Subsection: Boise		3	14
Vancouver	207	13	
Group: Discussion		6	
Subsection: Vancouver Island		7	26
Virginia	198	3	
Subsections: Hampton Roads		10	
Richmond		4	17
Virginia Mountain (Formerly Western Virginia)	90	6	6
Washington	946	8	
Groups: Basic Sciences		2	
Electronics - Communication-Instrumentation		3	
Power		2	
Joint inspection tour		1	16
West Virginia	158	10	
Subsection: Tri-State		8	
Joint Inspection Trip: Section and Tri-State Subsection		1	19
Wichita	106	13	13
Worcester	103	8	8
	34,515		1,728

Total Sections, 89
Total technical groups, 100
Total Subsections, 54
Total attendance, 126,221

Table II. Branch Meetings Held During Year Ending April 30, 1951

Branch	Number
*Akron, University of	7
Alabama Polytechnic Institute	20
Alabama, University of	12
*Alberta, University of	—
*Arizona, University of	25
Arkansas, University of	8
*British Columbia, University of	32
*Brooklyn, Polytechnic Institute of	
Day Division	8
Evening Division	5
Brown University	4
*Bucknell University	—
California Institute of Technology	3
*California, University of	13
*Carnegie Institute of Technology	12
Case Institute of Technology	11
Catholic University of America	6
Cincinnati, University of	13
Clarkson College of Technology	8
Clemson A & M College	6
Colorado A & M College	10
*Colorado, University of	14
*Columbia University	2
*Connecticut, University of	9
*Cooper Union	
Day Division	11
Evening Division	—
*Cornell University	10
*Delaware, University of	7
*Denver, University of	11
*Detroit, University of	9
*Drexel Institute of Technology	10
Duke University	5
Fenn College	6
*Florida, University of	6
George Washington University	10
Georgia Institute of Technology	10
Harvard University	5
Howard University	8
Idaho, University of	14
Illinois Institute of Technology	13
*Illinois, University of	16
Chicago Division	6
*Iowa State College	11
Iowa, University of	25
*Johns Hopkins University	15
Kansas State College	7
*Kansas, University of	11
Kentucky, University of	11
*Lafayette College	8
Lehigh University	5
Louisiana Polytechnic Institute	13
*Louisiana State University	15
Louisville, University of	12
*Maine, University of	5
*Manhattan College	6
*Marquette University	16
*Maryland, University of	1
*Massachusetts Institute of Technology	17
Massachusetts, University of	5
*Michigan College of Mining and Technology	12
Michigan State College	11
*Michigan, University of	7
Milwaukee School of Engineering	10
*Minnesota, University of	11
Mississippi State College	15
*Missouri School of Mines and Metallurgy	7
*Missouri, University of	9
Montana State College	9
*Nebraska, University of	13
Nevada, University of	11
Newark College of Engineering	5
*New Hampshire, University of	5
*New Mexico College of A & M Arts	11
*New Mexico, University of	8
New York, College of the City of	17
*New York University	
Day Division	19
Evening Division	5
*North Carolina State College	10
North Dakota State College	11
*North Dakota, University of	8
*Northeastern University	32
*Northwestern University	12
Norwich University	7
*Notre Dame, University of	8
Ohio Northern University	12
*Ohio State University	10
*Ohio University	7
*Oklahoma A & M College	8
*Oklahoma, University of	9
*Oregon State College	12
*Pennsylvania State College	11
*Pennsylvania, University of	7
Pittsburgh, University of	25
*Pratt Institute	8
*Princeton University	11
Puerto Rico, University of	2
Purdue University	8
*Rensselaer Polytechnic Institute	7

Table II (continued). Branch Meetings Held During Year Ending April 30, 1951

Branch	Number
*Rhode Island, University of	5
Rice Institute	5
Rose Polytechnic Institute	10
*Rutgers University	10
Santa Clara, University of	4
South Carolina, University of	13
South Dakota School of Mines and Technology	9
South Dakota State College	10
*Southern California, University of	6
*Southern Methodist University	12
*Stanford University	8
Stevens Institute of Technology	—
Swarthmore College	3
*Syracuse University	9
Tennessee, University of	4
*Texas, A & M College of	1
*Texas Technological College	14
*Texas, University of	15
Texas Western College Sub-Branch	7
*Toledo, University of	5
Toronto, University of	3
*Tufts College	9
*Tulane University	7
Union College	10
United States Naval Academy	—
*Utah, University of	9
Vanderbilt University	10
Vermont, University of	12
Villanova College	10
Virginia Military Institute	2
Virginia Polytechnic Institute	27
*Virginia, University of	11
Washington, State College of	11
*Washington, University of	10
Washington University	8
*Wayne University	4
West Virginia University	5
Wisconsin, University of	8
*Worcester Polytechnic Institute	4
*Wyoming, University of	10
*Yale University	5
Total Branches, 133	1,303

* Joint AIEE-IRE Branches.

Table III. Section Meetings Held During Last Three Fiscal Years

	Fiscal Year Ending April 30		
	1949	1950	1951
Number of Sections	85	87	89
Number of meetings held	1,613	1,674	1,728
Average number of meetings	19	19	19
Total attendance	131,936	141,905	126,221
Average attendance per meeting	82	85	73

Table IV. Branch Meetings Held During Last Three Fiscal Years

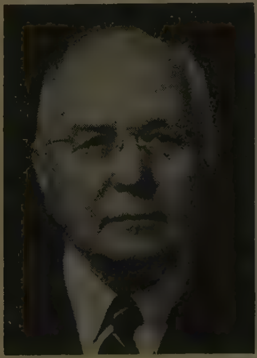
	Fiscal Year Ending April 30		
	1949	1950	1951
Number of Branches	129	130	133
Number of meetings held	1,405	1,318	1,303
Average number of meetings	11	10	10
Total attendance	105,290	81,815	63,369
Average attendance per meeting	75	62	49

AIEE PERSONALITIES . . . . .

Frank Thornton, Jr. (A '10, F '21, Member for life), engineering manager, association activities, Westinghouse Electric Corporation, East Pittsburgh, Pa., has retired after 42 years' service. Born in St. Joseph, Mo., on July 10, 1886, Mr. Thornton was graduated from the University of Missouri in 1908 with a bachelor of science degree in electrical engineering. He then attended the Technical College, Charlottenburg, Germany, for postgraduate studies. Mr. Thornton joined Westinghouse in 1909 and was assigned to the Engineering Department where he specialized in electric heating. In 1914 he was made section engineer in charge of electric heating and in 1918 was appointed engineering manager for the company plant in Mansfield, Ohio. He returned to East Pittsburgh as general engineer in domestic engineering in 1930, and one year later was made engineering manager of association activities. He is a member of The American Society of Mechanical Engineers, the Institute of Radio Engineers, and the International Association of Electrical Inspectors. Since the organization of the codes and standards committee of the National Electrical Manufacturers Association (NEMA) he has been committee chairman or vice-chairman, and a representative of NEMA on numerous committees of the American Standards Association. Mr. Thornton has been a very active member of the AIEE, having served on the following Institute committees: Safety (1931–44, Chairman, 1940–43); Technical Program (1939–50); Domestic and Commercial Applications (1940–44); and Power Co-ordinating (1947–49).

Frank Thornton, Jr.

John Morse (A '09, Member for Life), Vice-President, Shawinigan Water and Power Company, Montreal, Quebec, Canada, has retired after 44 years' service with the company. He was born on February 20, 1881, in Rattvik, Sweden, and came to this country in 1906. Before settling in Montreal, Mr. Morse was associated with the Maxwell Briscoe Motor Company, Tarrytown, N. Y., and the General Electric Company, Schenectady, N.Y. In 1907 Mr. Morse joined the Shawinigan Water and Power Company as a draughtsman. Four years later he was made superintendent of operation; in 1916, general superintendent; in 1938, assistant general manager; and in 1940, Vice-President of the company. He has served the Institute on the following committees: Transmission and Distribution (1920–21), and General Power Applications (1930–36).



John Morse

J. T. Thwaites (A '37, M '44), division engineer, Electronics Department, Canadian Westinghouse Company, Ltd., Hamilton, Ontario, Canada, has been appointed manager of electronic research for the company. He was graduated from Queen's University in 1925, and took two years postgraduate work in electronics. In 1929 Mr. Thwaites became associated with Westinghouse as a radio test engineer. The following year he joined the switchgear division and served as a special products engineer until his appointment as division engineer in charge of electronics in 1939. During World War II he was on loan to the United States War Department and also served in the United Kingdom. Mr. Thwaites is a member of the Engineering Institute of Canada. He has actively served the AIEE on the following committees: Electronics (1943–51); Electric Heating (1947–51); Electric Power Converters (1947–51); and Metallic Rectifiers (1950–51).

L. T. Rader (A '34, M '43), assistant to engineering manager, control engineering divisions, General Electric Company, Schenectady, N.Y., has been appointed manager of engineering. Dr. Rader was graduated from the University of British Columbia with a bachelor of science degree in electrical engineering in 1933. He received a master of science degree at the California Institute of Technology in 1935, and a doctor of philosophy degree in electrical engineering from the same institution in 1938. He joined General Electric in 1937 on the company's Test Course and in 1939 was assigned to the control engineering division as a design engineer. He remained there until 1945 when he accepted a position as Head of the Department of Electrical Engineering at the Illinois Institute of Technology, Chicago, Ill. He rejoined General Electric in 1947 as division engineer of the control divisions laboratory, and two years later he was made assistant to the manager of engineering. He is a member of Sigma Xi. Dr. Rader has served the Institute on the Industrial Control Devices Committee (1945–49), and the Student Branches Committee (1946–50).

A. E. Davison (A '13, M '44, Member for Life), consultant, Electrical Engineering Department, Hydro-Electric Power Commission of Ontario, Toronto, Ontario, Canada, has retired. He was born in Prescott

Ontario, Canada, on April 5, 1881, and received a bachelor of science degree from the University of Toronto in 1905. That same year he became associated with the Ontario Power Company, Niagara Falls, N.Y., as assistant inspector of generating stations. The next year he became assistant superintendent and engineering assistant with the Buffalo Pole Line Construction Company, Niagara Falls, N.Y. In 1909 Mr. Davison began his career with the Hydro-Electric Power Commission of Ontario. In 1915 he was appointed transmission engineer in which capacity he was in charge of the design and construction of all the transmission systems of the Commission. He has served the AIEE on the Transmission and Distribution Committee since 1931. He is a member of the Association of Professional Engineers of Ontario.

Hendley Blackmon (M '32, F '49), assistant manager, engineering association activities, Westinghouse Electric Corporation, East Pittsburgh, Pa., has been named manager of engineering association activities. Mr. Blackmon was graduated from the Georgia School of Technology in 1925 with a bachelor of science degree in electrical engineering. He was assigned to the Switchboard Engineering Department and in 1928 he was moved to the General Engineering Department. In 1932 he was named technical editor of the company's technical press bureau. He was appointed manager of the bureau in 1938, a position he held until 1945, when he resigned to join the McGraw-Hill Publishing Company as electrical editor of *Product Engineering*. He returned to Westinghouse in 1949 as assistant manager of engineering association activities. Mr. Blackmon served the Institute on the Safety Committee (1949–51), and on the Technical Program Committee (1950–51).

V. B. Bagnall (M '38, F '48), general commercial manager, Long Lines Department, American Telephone and Telegraph Company, New York, N.Y., has been named general manager of the western area, Long Lines Department. Mr. Bagnall was graduated from the University of Wisconsin in 1927 with a bachelor of science degree in electrical engineering, and later received a master of science degree from New York University. He joined the Long Lines Department in 1927 as a technical employee and later served in the Engineering Department. After serving as an officer in the United States Army during World War II he returned to the Long Lines Department where he has served as director of personnel, general plant manager, and general commercial manager.

E. W. Stone (A '34, M '37), superintendent, Electric Distribution Engineering Department, Central Illinois Light Company, Peoria, Ill., has been promoted to the position of manager, DeKalb Division, of the company. Mr. Stone has been associated with the Central Illinois Light Company since 1922 when he began his career as an electric meterman. After various promotions he was appointed distribution engineer and assistant superintendent, Electric Distribution Department, in 1942. He is a member of the Illinois Society of Engineers. Mr. Stone is an active member of the AIEE, having served on the following Institute committees: Membership (1945–46); Sections (1947–50); and Transfers (1950–51).

V. L. Dzwonczyk (A '36, M '43), sponsor engineer, electrical equipment section, American Gas and Electric Service Corporation, New York, N.Y., has been appointed operating sponsor to the operating vice-president. Mr. Dzwonczyk was graduated from Cornell University in 1935 with an electrical engineering degree. In 1937 he joined Holophane Lighting, Inc., and a year later he began his association with the American Gas and Electric Service Corporation. He is a member of the Illumination Engineering Society and Eta Kappa Nu.

C. H. Lang (A '43), Vice-President in Charge of Sales, Apparatus Department, General Electric Company, Schenectady, N. Y., has been appointed to a new post in charge of public relations for the company. In 1940 Mr. Lang was named Chairman of the Defense Co-ordinating Committee which co-ordinated General Electric's projects for the Armed Services.

H. B. Bryans (M '17, F '18, Member for Life), President, Philadelphia Electric Company, Philadelphia, Pa., has been elected a member of the Board of Managers of The Franklin Institute.

W. H. Bingham (M '37), manager, district apparatus and supply, Westinghouse Electric Supply Company, New York, N. Y., has been appointed eastern district manager. Mr. Bingham has been with Westinghouse since 1922.

OBITUARY • • • •

Friends of the late **Professor Dugald C. Jackson** have arranged a memorial service in his honor at the First Congregational Church, 11 Garden Street, Cambridge, Mass., on Sunday, October 21, at 4:00 p.m. An open invitation is extended to all who wish to attend. Professor Jackson (A '87, M '90, F '12, Honorary Member '44, Member for Life), died on July 1, 1951 (see *Obituary* in *EE, Aug '51, p 722*). He was a past President of the AIEE.

Allen Guthrie Dewars (A '17, M '27, F '44), manager, system planning, Operating Department, Northern States Power Company, Minneapolis, Minn., died on August 8, 1951. Mr. Dewars had just completed a term of office as Director of the AIEE. He was born on August 22, 1892, in Minneapolis, Minn., and received the degrees of bachelor of science in 1913 and electrical engineer in 1914 from the University of Minnesota. In 1914 he entered the employ of the St. Paul (Minn.) Gas Light Company as apprentice engineer and two years later he was advanced to the position of distribution engineer in the Electrical Department of the company. He served with the Army of the United States in World War I and in 1919 returned to the St. Paul Gas Light Company as assistant superintendent of distribution. Mr. Dewars was promoted to the position of superintendent of his department in 1925 and the following year, when the company was absorbed by the Northern States Power Company, he assisted in consolidating the electrical properties of the two companies in St. Paul. In 1929 he was transferred to the company headquarters in Minneapolis and in 1940 he attained the position of manager, system planning. Mr. Dewars was a Director of the AIEE from 1942–44, and at the same time was Vice-President representing the Great Lakes District (number 5). He served on the following Institute committees: System Engineering (1948–51); Production and Application of Light (1942–46); Instruments and Measurements (1943–44); and Special Committee on District Boundaries (1943–44).

Harrison Warwick Craver, Director of Engineering Societies' Library, New York, N. Y., died July 27, 1951. He was born in Owaneco, Ill., in 1876, and was graduated from Rose Polytechnic Institute. He worked several years as a chemist with various steel companies. He began his career as a librarian in 1900 with the Carnegie Library of Pittsburgh, Pa. There he organized and was head of the first technology department in any American public library. He became Director of the Engineering Societies' Library in 1917. A member of the American Library Association for 30 years he was its President (1937–38). He was also a member of the New York Library Club and the Keystone State Library Association.

Oscar George Miller (A '42), district manager, Sales Department, Rome Cable Corporation, New York, N.Y., died on July 7, 1951. He was born on January 24, 1888, and was graduated from Cornell University in 1911 with a bachelor of science degree. He began his career with the Standard Underground Cable Company in 1912, and subsequently became a district sales manager with the General Cable Corporation when the Standard Underground Cable Company merged with that concern. In 1936, Mr. Miller joined the Rome Cable Corporation as manager of its New York sales office.

MEMBERSHIP • • •

Recommended for Transfer

As there was no meeting of the Board of Examiners during the month of August, there is no transfer posting list this month.

Applications for Election

Applications for admission or re-election to Institute membership, in the grades of Fellow and Member, have been received from the following candidates, and any member objecting to election should supply a signed statement to the Secretary before October 25, 1951, or December 25, 1951, if the applicant resides outside of the United States, Canada, or Mexico.

To Grade of Member

Barraclough, A., The English Elec. Co. Ltd. of Stafford, England, New York, N. Y.

1 to grade of Member

AIEE Technical Subcommittees—1951–52

Communication Division

Communication Switching Systems

No subcommittees

Radio Communications Systems

Mobile Radio Subcommittee

A. C. Dickieson, *Chairman;* Bell Telephone Laboratories, Inc., Murray Hill, N. J.

C. M. Backer	Philadelphia, Pa.
I. F. Byrnes	New York, N. Y.
G. E. Dodrill	Washington, D. C.
L. B. Grew	New Haven, Conn.
J. W. Kearney	Mineola, N. Y.
L. P. Morris	Chicago, Ill.
J. E. Reid	Toronto, Ontario, Canada
C. E. Smith	Cleveland, Ohio
David Talley	New York, N. Y.

Point-to-Point Radio Subcommittee

H. P. Corwith, *Chairman;* Western Union Telegraph Company, 60 Hudson Street, New York 13, N. Y.

C. M. Backer	Philadelphia, Pa.
R. D. Campbell	New York, N. Y.
Edward Daskam, Jr.	New York, N. Y.
G. E. Dodrill	Washington, D. C.
L. W. Gregory	Baltimore, Md.
D. D. Grieg	Nutley, N. J.
S. C. Leyland	Newark, N. J.
Hubert Sharp	Denver, Colo.
L. R. Spaulding	Portland, Oreg.
J. M. Walsh	New York, N. Y.

Special Communications Applications

Electro-Acoustics Subcommittee

W. A. Ready, *Chairman;* National Company, Inc., 61 Sherman Street, Malden, Mass.

Melville Eastham	Cambridge, Mass.
T. W. Stringfield	Portland, Oreg.

Railroad Communications Subcommittee

R. H. Kline, *Chairman;* Westinghouse Electric Corporation, 3601 Washington Boulevard, Baltimore 27, Md.

W. D. Hailes	Rochester, N. Y.

Special Activities Subcommittee

G. J. Crowdes, *Chairman;* Simplex Wire and Cable Company, 66 Sidney Street, Cambridge, Mass.

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OF CURRENT INTEREST

New Harbor Radar for LeHavre, France, Demonstrated at Boston Harbor

A new harbor radar system which will guide vessels in fog has been built for the port of Le Havre, France, and was demonstrated recently in the harbor at Boston, Mass. The equipment was designed and constructed specifically for this purpose by the Raytheon Manufacturing Company, Waltham, Mass.

The tests conducted in Boston Harbor on Deer Island during July were made under actual conditions encountered in a busy harbor. Vessels were moved in and out of the harbor under conditions simulating zero-zero visibility. Orders were given to the vessel's pilot by means of 2-way radiotelephone equipment.

In order to meet the demands created by harbor work Raytheon designed and constructed the world's largest commercial type antenna (see cover). This antenna, which is 41 feet wide and weighs approximately 10,000 pounds, is more than three times larger than any shipboard-type radar antenna. It produces a beam width of only 42 minutes and has a power gain of approximately 10,000.

Since harbor radar equipment is normally installed ashore, the usual shipboard indicator would not be satisfactory because of the enormous wastage of plan-position indicator (P.P.I.) tube space due to land masses. To eliminate this, Raytheon has developed an adjustable offset-type indicator whereby the land masses can be moved off the screen and the radar station put on the edge of the screen. This has the effect of doubling the usable tube diameter, thereby providing greater magnification of objects viewed. The indicator used on the harbor radar system employs 16-inch tubes; thus, by offsetting and eliminating unwanted objects, the presentation is the same as would be seen on a 32-inch tube. In the harbor radar system tested at Deer Island, one standard indicator and three offset indicators were employed. The three offset indicators were offset in three different directions, thereby producing expanded pictures out toward the sea, in the channel between Deer Island and Long Island, and in the direction of the piers and docks of Boston Harbor. The standard indicator was used to check all directions simultaneously.

In order to keep track of all vessels anchored and moving in and out of the harbor, a newly developed reflection plotter was employed. This device, which employs a semimirror, projects a pencil mark from the plotting surface directly onto the P.P.I. tube. By taking fixes on objects at intervals and marking them on the plotting surface, the direction and speed of a vessel can be determined quickly and dangerous situations avoided. This is many times faster and safer than the indirect plotting methods used heretofore. Only one person is involved and plots are made directly on the radar image. Plots made on the plotting surface which is permanent can be erased quickly; thus, no replacement is required.

During the Deer Island tests, a method of transmitting radar information directly to remote points was tried for the first time. It employs a microwave relay link to transmit bearing, trigger, and video information to a remote point, which in this case was Boston's Commonwealth Pier. At Commonwealth Pier a microwave receiver was installed along with the terminal equipment and a standard 16-inch radar repeater indicator.

The radar repeater faithfully reproduced the picture as seen at Deer Island on any of the six independent ranges included in the equipment. This first transmission of radar information by microwave demonstrates the practicability of tying together a chain of harbor radar stations that would be required in a very complicated harbor. As a matter of fact, this demonstration shows that radar information could be transmitted great distances either by microwave or by coaxial cable similar to the method now employed to transmit network television programs.

In addition to the previously mentioned features, the harbor radar system employs the Raymark Beacon System for identification of specified vessels and also employs specially designed lubber-lines for obtaining bearings between two vessels and for obtaining fixes when using the special offset indicators.

The transmitter employs a selectable pulse length of 0.2 microsecond and 0.6 microsecond. The short pulse length is used chiefly to obtain finer detail where two closely spaced objects must be separated, whereas the longer pulse length is used when it is desired to see more distant objects. The exceedingly short pulse length, coupled with the extended video response of the equipment and the high definition antenna, combine to present a picture with excellent definition.

The harbor radar system naturally would be needed only during the periods of poor visibility caused by fog, rain, and snow. Since 3-centimeter equipment would be useless when it is needed, the choice of 10-centimeter wavelength for the harbor radar system was natural. Rain, snow, sleet, fog, or sea return have little effect on the new system.

Shown in position at the Deer Island location is the antenna of the microwave link used to transmit radar information from island to receiving station at Commonwealth Pier, South Boston, which served as harbor radar center for test and demonstration of new harbor radar equipment built by the Raytheon Manufacturing Company

Battery of four 16-inch radar scopes is shown at Deer Island, Boston Harbor, where tests were made before the radar equipment was shipped to port of Le Havre, France

Longest Microwave Relay System Opened for Transcontinental Telephone Service

The first telephone call coast-to-coast along the new microwave radio-relay skyway of the Long Lines Department of the American Telephone and Telegraph Company was made on August 17, 1951. Supplying a new backbone telephone route, vital to civilian and military needs of the nation, the project is the longest microwave system in the world. The new facilities for the first time will send telephone conversations across the continent by radio rather than wire or cable.

Designed to carry television as well as telephone messages, construction for temporary operation on the west-to-east channel was speeded up at the request of the State Department in order that the Japanese Peace Treaty ceremonies on September 4 could be televised. President Truman made the opening address. All the large television networks in the East broadcast the event. The system also provides for one east-to-west channel for television.

200-foot steel tower at Salt Lake City Junction overlooking Salt Lake City and Great Salt Lake in the distance. This is one of the 107 stations on the Long Lines Transcontinental radio-relay system

Built in about three years at a cost of $40,000,000, the system will relay calls along a chain of 107 microwave towers, spaced about 30 miles apart. The tremendous distances involved, together with the large number of radio channels required, posed a new set of problems for the Bell Telephone Laboratories. Three new developments provided the answers. First, a new electronic tube which performs at superhigh frequencies; second, an improved metal lens which will handle thousands of simultaneous telephone calls; and third, a unique system of filters representing a new contribution to the field of communications. This electronic equipment was made and installed by the Western Electric Company, manufacturing unit of the Bell Telephone System.

Messages will ride superhigh-frequency radio waves in the 4,000-megacycle range (4,000,000,000 cycles), compared to the ordinary radio broadcasting range of 550–1,600 kc (550,000–1,600,000 cycles). Radio waves used in the relay system are about three inches in length as against wavelengths of about 1,000 feet for frequencies in the middle of the standard broadcast band. Amplifying equipment in each relay station boosts the power of the radio signals ten-millionfold, then they are focused in a narrow beam by the directional antenna and sped on to the next tower where the process is repeated.

The radio-relay route will become the seventh telephone highway to cross the great western expanse of the country. Telephone engineers point out that the radio-relay system will not replace other types of communications but will supplement those already in operation.

EMC Convocation Stresses Shortage of Engineers

A convocation of engineers, educators, and industrialists to discuss the procedure to maintain and increase the national supply of engineers needed for civilian economy and the Armed Services is to be held by the Engineering Manpower Commission (EMC) of Engineers Joint Council at the University of Pittsburgh, Pittsburgh, Pa., September 28. This meeting was arranged by the Engineers' Society of Western Pennsylvania and its President, G. A. Shoemaker, will act as chairman. The theme of the convocation is "Engineering—Its Future."

The purpose is to inform the engineering profession about the critical shortage of engineers and the program of the Engineering Manpower Commission, and to invoke co-operation in its execution. In the main this program is to convince the general public of the vital importance of the technical man to the American way of life.

The morning session will be opened by A. C. Monteith, Vice-President, Westinghouse Electric Company, Pittsburgh, Pa. His talk, "Reflected Light is Not Enough," will include the necessity for engineering development for our welfare and security and the necessity for making the general public realize the importance of engineering to them. The next speaker will be S. C. Hollister, Dean, Cornell University, Ithaca, N. Y., whose talk "Resources—Present and Future" will review the school situation, present supply, and future need for a minimum satisfactory flow of engineering students, both undergraduate and graduate.

"Government Agencies and Policies" will be discussed by M. H. Trytten, National Research Council, Washington, D. C., who will describe the various governmental agencies and committees affecting the technical manpower supply and utilization, and will explain the functioning and interrelationship between the government bodies. The last speaker of the morning will be C. H. Brown, Eastman Kodak Company, Rochester, N. Y., and Chairman of the Engineering Manpower Commission, who will present "A Program for the Engineering Profession," in which will be discussed the attack on all problems previously considered by the Engineering Manpower Commission and the role that industry, the technical societies, and the schools can play in implementing the program. In the afternoon a question-and-answer session will be held.

New Technique Traces Underwater Structure of Chicago's Harbor

A newly designed electronic depth-finder, used normally on naval vessels to measure the ocean's depth, has been used success-

Future Meetings of Other Societies

American Standards Association. 33rd Annual Meeting. October 22–24, 1951, Waldorf-Astoria Hotel, New York, N. Y.

Audio Engineering Society. 3rd Annual Convention. November 1–3, 1951, Hotel New Yorker, New York, N. Y.

Engineers' Council for Professional Development. 19th Annual Meeting. October 19–20, 1951, Hotel Statler, Boston, Mass.

National Association of Corrosion Engineers. South Central Region. October 18–20, 1951, Corpus Christi, Tex.

National Conference on Industrial Hydraulics. 7th Annual Conference. November 8–9, 1951, Sherman Hotel, Chicago, Ill.

National Council of State Boards of Engineering Examiners. 30th Annual Meeting. October 21–24, 1951, Hotel Statler, Boston, Mass.

National Electrical Contractors Association. Annual Convention. October 9–12, 1951, Shoreham Hotel, Washington, D. C.

National Electrical Manufacturers Association. November 12–15, 1951, Haddon Hall Hotel, Atlantic City, N. J.

National Electronics Conference. October 22–24, 1951, Edgewater Beach Hotel, Chicago, Ill.

National Farm Electrification Conference. October 9–10, 1951, Hotel Gibson, Cincinnati, Ohio.

National Research Council. 1951 Conference on Electrical Insulation. October 29–31, 1951, National Bureau of Standards, Washington, D. C.

National Safety Congress and Exposition. 39th Annual Meeting, October 8–12, 1951, Chicago, Ill.

National Standardization Conference. 2nd Annual Conference. October 22–24, 1951, Waldorf-Astoria Hotel, New York, N. Y.

Pennsylvania Electric Association. Fall Meeting, Prime Movers Committee. November 1–2, 1951, Fort Stanwix Hotel, Johnstown, Pa.

Pennsylvania Electric Association. Fall Meeting, Transmission and Distribution Committee. October 11–12, 1951, Hotel Concord, North East, Pa.

Radio Fall Meeting. Sponsored jointly by the Radio Television Manufacturers Associations of Canada and the United States. October 29–31, 1951, King Edward Hotel, Toronto, Ontario, Canada.

The American Society of Mechanical Engineers. Annual Meeting. November 25–30, 1951. Haddon Hall Hotel, Atlantic City, N. J.

The Electrochemical Society, Inc. Semiannual Meeting. October 9–12, 1951, Hotel Statler, Detroit, Mich.

fully to locate the level of bedrock under deep silt deposits in the harbor at Chicago, Ill. Time and money saved by this method over the usual technique of tedious test boring would indicate an important milestone has been reached in geological survey work under water.

The experiments were conducted under the joint auspices of the Department of Interior and the City of Chicago along the Chicago waterfront where a new Central District Filtration plant is to be constructed north of the Navy pier. From this plant a tunnel is to be dug 5.1 miles north-northwest parallel to the shore line to a distribution center. Since the tunnel must be dug 50 feet below the top of bedrock, a survey to locate this level under silt and hard pan was necessary.

The equipment used was a standard depth-finder developed and manufactured by the Edo Corporation, College Point, Long Island, N. Y., for the United States Navy. It operates on the principle of sonar using a sonic signal emitted from a transducer. The time required for the signal to bounce back from the ocean floor, or in this case the upper surface of bedrock, is translated into terms of feet and provides highly accurate measurement. Soundings are recorded automatically and continuously on graph paper.

For the purposes of the Chicago tests the equipment was carried in a tug boat with the transducer slung over the side on a davit. The water depth in Belmont Harbor ranged from 10 feet to 25 feet with the bedrock about 110 feet below that.

It was found that soundings at as many as five to six test locations per hour could be taken. The relatively lengthy intervals between soundings was required to move to a new position and to pin-point the geographical location. This compares with the full day generally required to make one test boring. Beside saving time, there is a considerable cost saving as well since much equipment, a tug boat, and barge, as well as a crew of men, are required for boring operations.

The accuracy of sonar measurement was ascertained by making soundings where borings had been previously made. In every case the measurements were the same.

The time and money-saving advantages of the use of sonar equipment for this type of geological survey work are considered significant for a number of uses besides that of checking the level of bedrock. One such use could be the establishment of accumulation of siltage behind dams. From this information, the rate of silt formation can be established easily and at frequent intervals, so that the life expectancy of the project can be predicted accurately and realistically. Another valuable use is seen in checking erosion caused by the influence of moving water on abutments, piers, or other underwater structures.

Versatile Crane Has 7 Control Functions

This 3-ton capacity, double-bridge, monorail crane handles 4,500,000 pounds of bar stock annually in the General Electric Company's Small and Medium Motor Division's plant at Lynn, Mass. Seven control functions are involved in the crane's operation: longitudinal and cross travel of the cab, rotation of cab and grab (360 degrees), vertical travel of grab (floor clearance from 1 inch to 9 feet 6 inches), tilting of grab (8 degrees forward, 12 backward), rotation of forks and prongs (90 degrees), and raising and lowering of prongs. Main element of the equipment is the grab, a steel frame suspended by pulley and cable, which is equipped with three movable forks and safety prongs. Flexibility of the arrangement provides quick, efficient, and selective handling of stock that consists of 12 shapes, 75 specifications, and 800 sizes

Automatic Simplex Switching for Carrier Systems Developed

A revolutionary new automatic simplex-type switching development for power-line carrier installations has been designed and is in production by Motorola Inc., Chicago, Ill.

The electronic transfer unit designed for Motorola Research Line Carrier equipment is so precise in its operation that a circuit hardly can be distinguished from a well-balanced duplex circuit, although it operates on only one frequency.

All switching is accomplished in response to speech itself. A fraction of a second's hesitation allows for line clearance and either party may begin to talk. Once speech is started, the line is open only the one way until the moment speech again stops.

This form of switching has been developed for a variety of reasons. Among them are:

1. It allows party-line communications between several points, which full duplex operation cannot accomplish; 2. It operates on a single frequency eliminating the complexities of full duplex-type operation; 3. It does not require a press-to-talk button and circuit and, as a result, allows incorporation of automatic simplex-operated circuits into standard telephone systems.

Three major features incorporated in the design provide the advanced switching operation: 1. Extremely rapid speed of operation; 2. Complete freedom from inserting "click" into the circuit; and 3. The inclusion of asymmetrical time constant circuits whose operation in the direction of closing has different time constants than when opening.

The electronic transfer unit uses no relays because relay operation is considered to be too slow. Because the blocking and actuating of both the transmitter and the receiver were required to be accomplished electronically, the electronic transfer unit was first designed and transmitters and receivers have been designed to work in conjunction with it.

A typical operative cycle is as follows. In 2 milliseconds after speech is started, the unit automatically begins operation by first blocking the incoming receiver. The transmitter is started 0.4 millisecond later. The signal, when received at the distant end, first locks out the transmitter. This requires 0.4 millisecond. Then 0.4 millisecond later the receiver squelch is opened and the audio signal applied to the receiver output terminals. Thus, 3 milliseconds after speech is started at one end of the circuit, it emerges on the receiver output terminals at the other end of the circuit. (Line propagation time is neglected.)

At the cessation of speech, an arbitrary delay is inserted before switching action can begin. This may be adjusted manually from 30 to 500 milliseconds. At the end of the delay, the local transmitter is cut off. The remote receiver squelch closes 0.4 millisecond later. Five milliseconds after this the block is removed from the remote transmitter, and then 5 milliseconds later the local receiver is unblocked to receive the reply from the remote end of the circuit.

Experts Meet to Promote Rural Electrification in Europe

Experts on rural electrification from eight countries attending a United Nations Economic Commission for Europe (ECE) meeting at Geneva, Switzerland, recently called for a general study of technical and economic experience in rural electrification in order to permit, for the first time, all countries to benefit from the experience gained in this field by the more industrialized countries of Europe.

The larger purpose of the experts' work is to improve the living conditions of rural populations and to increase farm productivity, especially in the economically underdeveloped areas of Europe. The original proposal for the study was made by the Yugoslav delegation to ECE as a means of providing practical assistance to governments in their efforts to improve the lot of small and medium farmers in Europe.

The experts state that "the study should endeavour to discover, in the light of the experience acquired in the technically more advanced countries of Europe, the best way of carrying out the electrification of an agrarian country, taking into account not only the more technical problems of production, distribution, and application of power, but also the primarily economic questions of tariffs and financing and the organizational problems of co-operative use of equipment, training of farmers, . . . "

Specialists from Austria, Belgium, France, Italy, Sweden, the United Kingdom (including representatives of the Occupation Authorities of the Western Zones of Germany), the United States, and Yugoslavia, as well as from the Food and Agriculture Organization, participated in the 2-day first session of the ECE Group of Experts for the Study of Rural Electrification.

E. G. Bailey Receives 1952 John Fritz Medal

Ervin George Bailey, Past President of The American Society of Mechanical Engineers and Vice-President of Babcock and Wilcox Company, was selected by the John Fritz Medal Board of Award to receive the 1952 John Fritz Medal and Certificate "for outstanding engineering achievements in the field of combustion and distinguished service to his fellows in advancing the engineering profession."

The John Fritz Medal, established in 1902 by friends of John Fritz on the occasion of his 80th birthday to honor him for his great contributions in the manufacture of steel and in the advancement of industry generally, is perpetuated by the four leading engineering professional societies, AIEE, American Society of Civil Engineers, American Institute of Mining and Metallurgical Engineers, and The American Society of Mechanical Engineers as a joint honor for scientific or industrial achievement in any field of pure or applied science, without restriction on account of nationality or sex.

This award to Mr. Bailey is the culmination of a long series of honors which have been bestowed upon him for his achievement and leadership in steam and combustion engineering and in professional activities. He has been granted nearly 100 patents involving improvements in efficiency and operation in fuel burning and steam generation. As an important aid to efficient combustion, he developed a boiler meter now in general use, manufactured by a company bearing his name, and which he headed as president. He has been honored by leading educational institutions with honorary doctorates in engineering and science. He has always been interested in the education of young men for the profession of engineering, and in their later selection and training for their life work. He assisted in the organization and was chairman of the Engineering Manpower Commission of the Engineers Joint Council.

Mr. Bailey is a member of several national professional societies and of several honorary engineering societies. He is one of the few American engineers who are honorary members of The Institution of Mechanical Engineers, London, England.

American Institute of Physics Celebrates 20th Anniversary

The 20th anniversary of the American Institute of Physics will be celebrated at the Hotel Sherman in Chicago, Ill., October 23–27, by a joint meeting of the Founding Societies of the Institute. It is expected that this meeting, which will bring together the leading societies representing the field of physics in the United States, will be the largest gathering of physicists ever held.

Member societies which will hold their regular fall technical meetings during the 5-day anniversary celebration are the American Physical Society, the Optical Society of America, the Acoustical Society of America, the Society of Rheology, and the American Association of Physics Teachers. The American Crystallographic Association, an affiliated society of the American Institute of Physics, will also participate in the Anniversary Meeting. Several hundred papers of original research will be presented.

125,000-Kw Unit Completes Sewaren Generating Station

The fourth turbine-generator unit, the largest 3,600-rpm machine in operation anywhere, has just been put in service at the Sewaren Generating Station of Public Service Electric and Gas Company. This 125,000-kw unit increases the electric generating capacity of the station to 455,000 kw, and that of the entire Public Service system to 1,620,300 kw.

Sewaren Generating Station was started with two 110,000-kw units in operation in the fall of 1948. A third unit of the same size was added in 1949, and the addition of the fourth unit now completes the station. The initial steam pressure of the new turbine-generator at Sewaren Station is 1,500 pounds per square inch and the steam temperature is 1,050 degrees Fahrenheit. Steam is supplied by a single large boiler equipped to burn either coal or oil fuel, and capable of evaporating 950,000 pounds of water per hour. The steam, after passing through several stages of the turbine, is returned to the boiler and is resuperheated to 1,000 degrees Fahrenheit, and then re-enters the turbine.

To keep pace with the present industrial, commercial, and residential demands for electricity in the important areas of New Jersey the company serves, and in anticipation of future power requirements, the company also has started construction for the installation of two new 145,000-kw turbine-generators at its Kearny Station. One of the new Kearny Station units is expected to be placed in service in the fall of 1952 and the other in the spring of 1953. The company has also ordered a 185,000-kw machine for installation at Burlington Generating Station for service in the summer of 1954.

When these additional units are in service, the total electric generating capacity of the Public Service system will be 2,095,300 kw, continuing to be one of the largest steam-electric systems in the country.

Community TV Antenna System Increases Station Coverage

The first public demonstration of the Radio Corporation of America's (RCA) new community television (TV) Antenaplex System, designed to bring television programs to areas where reception previously was poor or unavailable, was presented recently at Pottsville, Pa.

Providing TV signal pickup and distribution service for an entire community, the new system consists of a master antenna assembly, mounted on a tall mast on the highest nearby elevation; a network of coaxial cable, strung over utility poles from the antenna site through the areas to be served; amplifiers, mounted on poles at fixed intervals to boost the strength of the signals; and lead-off lines, terminating in wall or baseboard outlets in the homes of set-owners subscribing for the service. On the antenna mast are separate elements tuned for each channel on which programs are available.

The system has proved its ability to eliminate the TV blind spots represented by mountain-ringed communities as well as those on flat terrain where the nearest TV stations are too remote to permit reception with individual roof-top antennas.

The new system makes use of roof-top antennas unnecessary. Local operating companies offer the service for a fixed installation fee, plus a monthly service charge.

By using tall master antenna towers which would be impractical for use by individuals from the standpoints of size, weight, and cost, and by mounting these towers on geographical vantage points, it is possible to extend the radius of coverage from an average of 45 miles to as much as 130 miles in some cases. With such master-receiving antennas in use in communities ringing a broadcast station at distances of 130 miles, the area of coverage would be extended from one of about 6,000 square miles to one of more than 50,000 square miles.

Largest Liquid Rheostats to Regulate Wind Tunnel

The world's largest liquid rheostats, to help test full-size jet engines, guided missiles, and wing sections and fuselages of aircraft, will be built by Westinghouse Electric Corporation at its Buffalo, N. Y., plant.

They will be used to regulate the speed of large electric motors at a new wind tunnel at the Arnold Engineering Development Center in Tullahoma, Tenn. The rheostats are part of $20,000,000 worth of electric equipment which Westinghouse is building for the new project.

The extremely high horsepower rating of the big motors make it necessary to build the rheostats with greater capacity than ever before. Each liquid rheostat is more than 20 feet high and consists of three 9-foot-high tanks in which an alkaline solution is circulated. At the bottom of each tank is a stationary nickel-clad steel plate or electrode. A similar electrode is attached to a movable plunger-like support at the top of the tank. Current passes from one electrode to another through the alkaline solution. As the top electrode plate is lowered, the flow of current is increased, thus speeding up the motor. Pulling the plates farther apart cuts down the current flow and the motor speed. The three moving electrodes are hooked up together so the three tanks operate as a single unit.

Two of the motors in this installation will be the most powerful in the world.

High-Speed Crystal Clutch Uses Nearly Zero Current

A piezoelectric crystal clutch having a high speed of response and negligible current drain has been developed for use in high-speed computers by Ernest Codier of the National Bureau of Standards staff. In the only clutch model thus far constructed, the output shaft delivered useful torque in as little as 0.2 millisecond after voltage was applied. Output torque of the engaged clutch was approximately 16.5 ounce-inches at 400 volts excitation, or 21 ounce-inches for 500 volts. The no-voltage drag torque, however, was about 7.5 ounce-inches, a substantial fraction of the engaged torque.

The crystal clutch construction is simple. The output disk is located between two rotating members: a thin, flexible crystal pressure plate and a heavier mounting plate or input disk. Three Bimorph crystal elements, which bend when opposite potentials are applied to different parts of the crystal surfaces, are spaced at 120-degree intervals. When the exciting voltage is applied, the crystals press against the pressure plate at a radius of 1.5 inches, pinching the output disk between the pressure plate and the input disk.

The complete clutch assembly includes internal bearings for the output shaft, bearings and mounts for the entire assembly, a drive pulley, and slip rings for transmitting the exciting voltage to the rotating assembly. The clutch and its mounting occupy a space about 6 inches in diameter and a little more than an inch long.

Speed of response, the principle design goal, is related to the inertia and loading of the output system, the available torque, the distance the crystal pressure point must move before it begins to pinch the output disk, and the resonant frequency of the crystal itself. The resonant frequency sets the ultimate limit for speed of response. Since increased crystal thickness is favorable to high resonant frequency but unfavorable to high sensitivity, dimensions must be a matter of compromise and judgement. Rochelle-salt crystals are used in the present clutch.

1951 Daniel Guggenheim Medal Presented to I. I. Sikorsky

Igor Ivan Sikorsky has been awarded the Daniel Guggenheim Medal and Certificate for 1951 "for a lifetime of outstanding contributions to aeronautics, including pioneering with multi-engine airplanes, flying boats, amphibians, and helicopters."

The Daniel Guggenheim Medal was created for the purpose of honoring persons who make notable achievements in the advancement of aeronautics. Provision for the medal was made in 1928 by the gift of a fund from the Daniel Guggenheim Fund for the Promotion of Aeronautics. Selection of the medalist each year is made by a Board including all former recipients of this medal who reside in the United States, and representatives of several major professional societies; The American Society of Mechanical Engineers, the Society of Automotive Engineers, and the Institute of the Aeronautical Sciences.

Battelle Memorial Institute to Establish European Branch

Battelle Memorial Institute, Columbus, Ohio, one of the largest independent industrial research foundations, will establish a European branch of its laboratories to serve the European economy, it was announced recently. The decision follows a recently completed survey of scientific and industrial conditions in Europe.

The staff of Battelle feels that the accumulated knowledge and experience gained through its service to American industry can do much to help industry in Europe increase its productivity and elevate the standards of living there. At the same time, it is felt that European science has much to offer American scientists, especially in the way of fundamental knowledge and research. By working together, research men of both continents will benefit from association with each other. It is believed further that the establishment of an international research center will do much to promote world peace by encouraging understanding and friendship among scientists of all nations.

Westinghouse to Build World's Largest Turbine-Generator

The Philadelphia Electric Company has placed an order with the Westinghouse Electric Corporation for a 200,000-kw turbine-generator, largest single-shaft unit ever to be built. The turbine-generator will be installed at the new Cromby Station near Phoenixville, Pa., where, together with a 150,000-kw unit already under contract, it will bring the station's total capacity to 350,000 kw.

The turbine will be designed for steam at an initial pressure of 1,800 pounds per square inch and a temperature of 1,000 degrees Fahrenheit, with reheat to 1,000 degrees Fahrenheit, and will be a triple exhaust unit.

West Berlin Sees TV Demonstration. Approximately 1,250,000 residents and visitors to West Berlin, Germany, saw television programs broadcast daily by a 29-man Radio Corporation of America (RCA) crew for two weeks recently. The installation of broadcasting facilities was made in 85 hours as a result of day and night effort on the part of RCA engineers and their German assistants. The equipment was shipped from the United States under the sponsorship of the Economic Co-operation Administration.

LETTERS TO THE EDITOR

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

Magnetic Amplifier Expansion

To the Editor:

In the military field, magnetic amplifiers are already an accepted necessity. A large number of naval specifications now require magnetic amplifiers without electronic tube substitutions permitted. In atomic power work where reliability is paramount, there is a general swing to magnetic amplifiers for all manner of applications including d-c power supplies and the various control system components. Many applications are being sought in aircraft and one autopilot operation will use over a million dollars worth of magnetic amplifiers per year. Other applications in aircraft are heater controls, wing flap controls, and so forth.

The reason for applications varies considerably, and the magnetic amplifier is not dependent upon any one characteristic for its acceptance or choice in comparison with other methods. It can actually be built with lower losses, less heat dissipation, and smaller space than comparable electronic devices, such as the power stage for handling small servo motors and the like. Thus, space and heat economy are the ruling characteristic in some applications. In others, the comparative shock-proofness is a requisite quality. In other applications the reliability and long life predominate as the characteristic principally determining the choice of the magnetic amplifier over electronic or rotating devices.

The industrial control application of magnetic amplifiers brings in the cost factor more predominantly than any other field, particularly for the less important controls. However, for the more important controls handling important processes or expensive machinery, there is no question about the justification for the magnetic amplifier. The principal deterrent is simply the time required to change over design from current style to those incorporating the magnetic amplifier. Already it has found its way into an imposing list of industrial applications including steel mill controls, reel drives of various kinds, motor controls, voltage and frequency regulators, speed regulators, volts per cycle regulators, elevator controls, aircraft controls, paper mill applications, and a host of others.

Likewise its use as the equivalent of a d-c current transformer for heavy current d-c busses has been accepted and is spreading.

There are many unsolved problems in the magnetic amplifier. It is a nonlinear circuit with many facets as yet uncovered. A recent bibliography of literature and patents covers 52 pages of references to technical work bearing on the magnetic amplifier and the associated iron and nonlinear circuit characteristics. Yet today one finds new characteristics and possible performance features being discovered at a still increasing rate. When it is realized that only the simplest of the nonlinear circuits have been explored at all and these not too thoroughly, it is evident that the magnetic amplifier is only a small start on the application of nonlinear circuit devices involving saturation. It will be interesting to watch the growth of the magnetic amplifier in industry.

E. L. HARDER (F '48)

(Westinghouse Electric Corporation, East Pittsburgh, Pa.)

Transformer Design

To the Editor:

The article, "Design of Broad-Band Transformers for Linear Electronic Circuits" by H. W. Lord (*EE, Nov '50, pp 1020–25*), gives a noteworthy contribution to the design of broad-band transformers. The author deserves appreciation especially for stressing the necessity for co-operation of electronic engineers and transformer designers in the development of broad-band transformers.

I would like to contribute an example which shows that an ideal design of a transformer for class-B high-level plate modulation requires a very close co-operation between the designer of the radio-frequency transmitter and the designer of the class-B modulator when the transmitter is wide-band modulated, for example, a broadcaster operating on a relatively low carrier frequency.

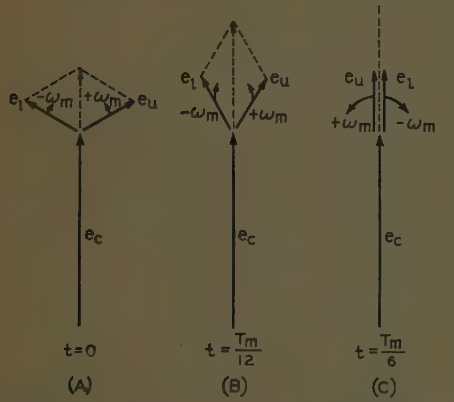

Figure 1. The voltage relationships at three different moments of an audio-frequency period

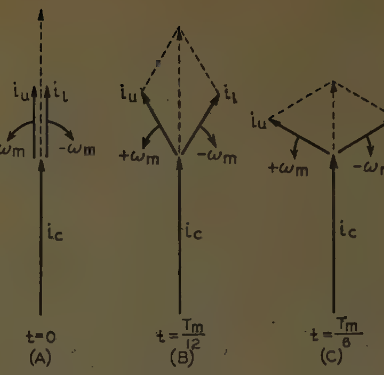

Figure 2. The current relationships corresponding to the voltage diagrams of Figure 1

The plate load of the radio-frequency valves, that is, the input impedance of the radio-frequency output filter, generally shows a reactive component for the side-band frequencies. Consequently the side-band radio-frequency plate currents are not in phase with the radio-frequency plate voltages.

Figures 1 and 2 show the voltage and current relations at three different moments of an audio-frequency period (T_m). e_c is the carrier, e_u the upper side-band voltage (of angular frequency $+\omega_m=\frac{2\pi}{T_m}$ relative to the carrier vector e_c), and e_l the lower side-band voltage (angular frequency $-\omega_m$). i_c, i_u, and i_l are the corresponding current vectors. Figures 1 and 2 represent the case where the plate load is capacitive at the upper side-band and inductive at the lower side-band frequency.

Consequently the current i_u is leading the voltage e_u (in the represented example by 60 degrees; compare Figures 1*A* and 2*A* or 1*B* and 2*B* or 1*C* and 2*C*), and the current i_l is lagging the voltage e_l. The sums $e_c+e_l+e_u$ and $i_c+i_l+i_u$ respectively represent the instantaneous values of the audio-frequency envelopes when they are represented as amplitude-modulated sine waves. The maximum of the current envelope, Figure 2*A*, will be reached anterior to the maximum of the voltage envelope, Figure 1*C*. As the envelopes correspond to the audio-frequency voltage and current delivered by the modulator, the radio-frequency stage does not reflect a purely resistive load to the modulation transformer. The character of the additional audio-frequency reactive load is the same as that of the reactive component of the radio-frequency plate impedance at the *upper* side-band frequency as derived here.

Thus, for the design of the modulator and modulation transformer not only the capacities of the transformer windings and of external capacitors have to be taken into account but also the frequency dependent capacity reflected from the modulated radio-frequency stage. Furthermore, if the radio-frequency output filter is designed so that the reactive component of its input impedance is inductive at the upper side-band frequencies, the radio-frequency stage reflects an inductance to the modulator which may successfully compensate the capacitive load of the modulation transformer.

This shows that the design of the modulated radio-frequency stage and of the modulator and modulation transformer cannot be separated. It explains why a modulation transformer gives different results even when operating with transmitters of equal power but different design.

R. GUERTLER

(Standard Telephones and Cables Proprietary, Ltd., Sydney, Australia)

Panel-Heating System

To the Editor:

In Clarence Frere's article, "Improving the Position of Electricity as Primary Energy for Space Heating" (*EE, July '51, pp 608–11*), there is a statement that "A panel-heating system has lower operating cost than the conventional heating systems, and this is particularly true with a ceiling panel installation which takes advantage of a larger radiation component." This is erroneous and I am sure that if Mr. Frere had made any field tests with his heating system he would be aware of what actually happens.

It is frequently stated in connection with panel-heating systems, electric and otherwise, that they cost less to operate because they do not heat the air. What keeps the air cool? If we are to bring in an abnormal amount of fresh air in order to keep it cool, then we will carry away heat when this cool air contacts the panels and warm air is ejected. Surface temperatures of the floors and ceiling, with radiant heat panels, necessarily are above 70 degrees Fahrenheit, and I have yet to see a job in which the air would not come up to approximately the same temperature. The truth of the matter is that panel-heating systems cost more to operate for a very fundamental and obvious reason. The temperature difference of the panels in close proximity with the outdoors is considerably greater than with a conventional heating system. This additional thermal stress results in a 10 to 15 per cent greater cost of operation for ceiling-heating panel systems and as much as 30 per cent more for floor-heating systems. I suggest that Mr. Frere contact the Development Section of the Tennessee Valley Authority or the Rate Research Department of the Portland General Electric Company, or any other utilities who have studied carefully the operating costs of various electric systems.

Laboratory experiments may show that radiant-heating systems cost less to operate, but if they do it is because they were not properly executed and did not take into consideration all of the factors present in a typical heating system in the field.

It is also erroneous to say that capacity requirements may be reduced for panel-heating systems, as the actual heat loss is greater because of the greater thermal stress at the location of the panel. If Mr. Frere is thinking of a unit-heating system manually operated, he is correct, but modern unit-heating systems are not operated manually. Each one has its own thermostat to control each unit heater as an independent plant in each room. In addition, an outdoor thermostat is provided to adjust the capacity automatically to meet the changing conditions out-of-doors. Such a system does not require readjustment of the room thermostat, as stated by Mr. Frere. It is well to point out that a panel-heating system also is improved greatly by adjusting the capacity for the requirements. The fluctuation of temperatures shown in his Figure 1 is considerably reduced, particularly in mild weather where the power-on cycle would otherwise be much shorter.

Perhaps I am being too critical since Mr. Frere states that his results are based on laboratory experiments, and in this instance field checks should be made, as I am confident that his laboratory results will not hold up in the field. The suggestion that panel heating can benefit the power producer by providing reduced connected loads, better diversity, and better load factors is not necessarily true. In a well-insulated house, of which the great majority of electrically heated homes are today, connected load is not more than 15 per cent greater than the actual losses for the house. This excess capacity factor is the same as recommended for panel heating. The modern unit-heating system and the changing living habits in the American home have gone a long way to eliminate the old-fashioned idea of turning the heat off at night. It is true that a panel-heating system must continue to operate 24 hours a day, but such operation is desirable with any system. It is the 24-hour-a-day operation that improves the daily load factor, and it is the use of an outdoor thermostat or capacity control that improves the monthly load factor. There is not much of anything that will improve the annual load factor other than a well-directed sales promotion effort on the part of the utility.

Mr. Frere has not mentioned one of the principal irritations in panel heating, which does not appear in the laboratory; that is, the cold area next to the windows. Convection currents are set up around any window and with a radiant-heating system where there is no counter air circulation there is a strong cold air draft across the floor from the window. This does not provide the high degree of comfort implied by Mr. Frere. Radiant-panel-heating systems offer no control of the air; thus, a separate air-conditioning system is necessary in addition to the radiant-panel-heating system. This is particularly true because of the American habit of smoking cigarettes in great numbers. Certain features of radiant-panel heating are highly desirable to be incorporated in a home for the greatest comfort, but unless there is a provision for a gentle circulation of air I cannot accept the suggestion that the panel-heating system is the final solution to correct all deficiencies of other systems. For domestic space heating the best system is necessarily a compromise to give the customer the maximum comfort with a minimum cost (first cost as well as operating cost) in addition to safeguarding the utility, and this is generally a radiant-convection system using individual units or baseboard.

J. C. BECKETT (M'49)

(Wesix Electric Heater Company, San Francisco, Calif.)

NEW BOOKS • • • • •

The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

DISTRICT HEATING HANDBOOK. Third Edition. Edited and published by National District Heating Association, 827 North Euclid Avenue, Pittsburgh 6, Pa., 1951. 529 pages, illustrations, diagrams, charts, tables, $9^{1}/_{4}$ by 6 inches, cloth, $7.00. This handbook deals with design, practice, equipment, and supplies used in district heating. Completely rewritten and brought up to date, this third edition surveys the industry, considers plant design, water chemistry and corrosion, steam distribution, metering, building heating systems, consumers' process and accessory equipment, estimation and efficient use of steam, rates, sales activities, and hot water for district heating. Manufacturers' data on commercial products most used in the industry are given in the guide section of the book.

ELECTRICAL TRANSMISSION AND DISTRIBUTION REFERENCE BOOK. Fourth Edition. By Central Station Engineers of the Westinghouse Electric Corporation, East Pittsburgh, Pa., 1950. 824 pages, illustrations, diagrams, charts, tables, $11^{1}/_{4}$ by $8^{1}/_{2}$ inches, cloth, $6.00. This book serves as a practical reference for solving everyday problems in electric-power transmission. This fourth and completely rewritten edition contains essentially the material of the previous editions and three new chapters—Excitation Systems, Application of Capacitors to Power Systems, and Power Line Carrier Application.

ELEMENTS OF TELEVISION SYSTEMS. By G. E. Anner. Prentice-Hall, New York, N.Y., 1951. 804 pages, illustrations, diagrams, charts, tables, $8^{3}/_{4}$ by $5^{1}/_{2}$ inches, cloth, $10.35. This book is concerned with the basic principles and equipment. Part I is devoted to a study of closed systems, those that rely upon cable connections between sending and receiving apparatus. Part II considers the commercial telecasting system which uses a radio link in place of interconnecting cables. The third and last part deals with color television systems. Dot systems of television transmission are covered in an Appendix. Sets of problems are included at the end of the book.

(THE) GAS TURBINE MANUAL. By R. J. Welsh and G. Waller. Temple Press, Ltd., London, England, 1951. 243 pages, illustrations, diagrams, charts, tables, $8^{3}/_{4}$ by $5^{1}/_{2}$ inches, cloth, 25s. Intended as a text for students and a reference for power-plant engineers, this British book deals with various forms of gas turbines other than those used for aircraft. It covers fundamental theory and operational features of turbines used in locomotive, power station, and marine applications. A glossary of gas turbine terms, useful tables, and a bibliography are included. Design information on some 50 British and foreign gas-turbine plants also is given.

HIGH-FREQUENCY MEASUREMENTS. By A. Hund. Second edition. McGraw-Hill Book Company, New York, N.Y.; Toronto, Ontario, Canada; London, England, 1951. 676 pages, diagrams, charts, tables, $9^{1}/_{4}$ by 6 inches, linen, $10.00. This book provides procedures of measurements and presents the principles underlying a particular determination. In this second edition, methods are described which cover the band from audio to superhigh frequencies. The meter-kilogram-second system is used, and among the recent advances and revised items covered are measurements and instrumentation in connection with short waves, line and antenna measurements, measurements for amplitude modulation, phase modulation, and frequency modulation, signal-to-noise measurements, and modern high-frequency bridge procedures.

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ENGINEERING Societies Library books may be borrowed by mail by AIEE members for a small handling charge. The library also prepares bibliographies, maintains search and photostat services, and can provide microfilm copies of any item in its collection. Address inquiries to Ralph H. Phelps, Director, Engineering Societies Library, 29 West 39th St., New York 18, N. Y.

PHYSICAL GEOGRAPHY. By A. N. Strahler. John Wiley and Sons, New York, N. Y.; Chapman and Hall, Ltd., London, England, 1951. 442 pages, illustrations, diagrams, charts, maps, tables, $11^{1}/_{4}$ by $8^{1}/_{2}$ inches, linen, $6.00. This book is primarily concerned with explaining the processes and forms which develop in the atmosphere and hydrosphere and on the earth's land surfaces. It considers the earth as a globe, has map projections, maps and landforms, rocks and structures, weather and climate, natural vegetation, and soils. No scientific or mathematical knowledge is assumed; wherever a physical principle is used, the basic concepts are reviewed and explained.

(THE) PHYSICAL NATURE OF FLIGHT. By R. Holland, Jr. W. W. Norton and Company, New York, N.Y., 1951. 287 pages, diagrams, $8^{1}/_{2}$ by $5^{3}/_{4}$ inches, cloth, $4.00. Written for the nonaeronautical engineer by an aeronautical engineer, this book is a nontechnical discussion of the physical laws upon which flight is based, the action of the plane's components, and other aspects of practical flight. Each principle is explained in the light of everyday observation. Airplane design, flight performance, control, stability, and the potentialities of the future are among the subjects discussed.

POLYPHASE COMMUTATOR MACHINES. By B. Adkins and W. J. Gibbs. Cambridge University Press, American Branch, New York, N.Y., 1951. 230 pages, illustrations, diagrams, charts, $8^{3}/_{4}$ by $5^{1}/_{2}$ inches, linen, $4.00. Written by designers for students and engineers, this book describes the various types of polyphase commutator machines, including the most important methods of control and the characteristics obtained. Stressing the practical side, theory is dealt with in separate sections. A good prior knowledge of induction motor theory is needed for those interested in the theoretical treatment.

PROPERTIES OF LUBRICATING OIL AND ENGINE DEPOSITS. By C. A. Bouman. Macmillan and Company, New York, N.Y.; London, England, 1950. 170 pages, diagrams, charts, tables, $8^{3}/_{4}$ by $5^{1}/_{2}$ inches, cloth, $3.00. After a few brief chapters on the purposes of lubrication, classification of lubricating oils, and manufacture of lubricating oils, the author discusses at greater length such items as: viscosity, friction, volatility, oil consumption, cylinder wear, contamination, sludge deposits, carbon deposits, lacquer deposits, piston-ring sticking, maintenance, and testing of oils.

QUANTUM MECHANICS OF PARTICLES AND WAVE FIELDS. By A. March. John Wiley and Sons, New York, N.Y.; Chapman and Hall, Ltd., London, England, 1951. 292 pages, diagrams, charts, $9^{1}/_{4}$ by 6 inches, linen, $5.50. Intended for use by those without previous knowledge of the subject, this book covers both the quantum mechanics of wave fields and the older quantum theory of particles. Emphasis is on a clear understanding of the principles involved. The final chapter presents a revolutionary theory of fundamental length, a theory designed to meet some of the basic difficulties still present in the quantum theory.

RADIO AMATEUR'S HANDBOOK. Edited and published by the American Radio Relay League, West Hartford, Conn., 28th edition, 1951. 551 pages plus Vacuum Tube Data, Tables and Catalog Section, 144 pages, illustrations, diagrams, charts, tables, $9^{1}/_{2}$ by $6^{1}/_{2}$ inches, paper, $2.50. This standard manual of amateur radio communications covers the entire field from basic fundamentals to the latest techniques in equipment design and construction. One of the two new chapters deals with the design and construction of single-side-band suppressed carrier radio telephone transmitters. The other new chapter covers mobile techniques. The practical vacuum-tube data tables are completely up to date. The advertising section is considerably expanded to include some complete catalogues as well as many condensed ones.

RADIO HANDBOOK. 13th Edition. Edited by R. L. Dawley and Associates, published and distributed by Editors and Engineers, Ltd., 1300 Kenwood Road, Santa Barbara, Calif., 1951. 734 pages, illustrations, diagrams, charts, tables, $9^{1}/_{2}$ by $6^{1}/_{2}$ inches, fabrikoid, $6.00 plus $.25 postage, in United States; $6.50, foreign, for sale by Baker and Taylor Company, Hillside, N.J. Covering the field of short-wave or high-frequency radio, the thirteenth edition of this standard work emphasizes the principles of equipment design and signal propagation. Basic circuit elements and theory are dealt with. Equipment such as transmitters, antennas, receiving equipment, power amplifiers, power supplies, and test and measurement equipment are covered.

(A) ROMANCE IN RESEARCH, The Life of Charles F. Burgess, Student—Teacher—Researcher—Industrialist. By A. McQueen. Instruments Publishing Company, Pittsburgh, Pa., 1951. 429 pages, illustrations, 9½ by 6¼ inches, linen, $6.00. In addition to recording the personal life and the companies formed by Charles F. Burgess, noted researcher in electrochemistry, metallurgy, and chemical engineering, an appendix is included which covers his personal technical accomplishments on batteries, electrolytic iron and iron alloys, metal coating and electrorefining, corrosion, electrochemical processes, electric furnaces, electrochemical devices, and technical education. A list of his articles, technical reports, and patents, as well as publications and patents by other people in the fields in which Dr. Burgess was active, is included.

SERVOMECHANISMS AND REGULATING SYSTEM DESIGN, Volume I. By H. Chestnut and R. W. Mayer. John Wiley and Sons, New York, N. Y.; Chapman and Hall, Ltd., London, England, 1951. 505 pages, diagrams, charts, tables, 9¼ by 6 inches, linen, $7.75. Covering the principles of feedback control, this book, the first of a 2-volume set, is adapted to the needs of engineers and engineering students who have not had previous training or experience in the field of closed-loop control systems. It starts with the basic mathematics needed and a description of the nature of the physical problems involved, and proceeds to the solution of advanced designs. Numerous problems, illustrate and extend the text material, and a bibliography of pertinent references is included.

SHORT WAVE WIRELESS COMMUNICATION INCLUDING ULTRA-SHORT WAVES. By A. W. Ladner and C. R. Stoner. Fifth edition revised and enlarged. John Wiley and Sons, New York, N. Y., 1950. 717 pages, illustrations, diagrams, charts, tables, 9 by 5½ inches, linen, $8.00. This fifth edition has been enlarged and brought up to date. These chapters on history, push-pull, and diathermy have been deleted and replaced by new chapters on sound and vision signals, wave guides, and wireless telegraph circuits. The chapter on radio-frequency lines has been considerably enlarged and recast, and a chapter on methods of operation employed in wireless telegraphy has been added. This edition is not restricted entirely to short waves, principles common to both long and short waves being introduced wherever necessary.

SYNCHRONOUS MACHINES, Theory and Performance. By C. Concordia. John Wiley and Sons, New York, N. Y.; Chapman and Hall, Ltd., London, England, 1951. 224 pages, illustrations, diagrams, charts, tables, 9¼ by 6 inches, linen, $5.50. Intended primarily for the use of the practicing engineer, this book develops the fundamental circuit theory of the transient performance of synchronous machines used in predicting machine performance. Emphasis is on a rigorous mathematical development and on obtaining a fundamental physical understanding of their behavior. The general equations developed are applied to the calculation of transient short-circuit currents and torques; to steady-state power, torque, and current, both in operation and starting; and to voltage disturbances caused by sudden application of load.

TABLE OF ARCTANGENTS OF RATIONAL NUMBERS (Applied Mathematics Series 11). By J. Todd. United States Bureau of Standards, Washington, D. C., 1951. 105 pages, tables, 10½ by 8 inches, cloth, $1.50, for sale by Superintendent of Documents, United States Government Printing Office, Washington 25, D. C. Table 1, in addition to m^2+n^2 and Arctan (m/n), also gives Arccot (n/m). The angles are expressed in radians to 12 decimals and complete reductions of Arctan (m/n) are given for $0<m<n\leq 100$. Table 2 gives a list of those integers n not exceeding 2,089 for which Arctan n is reducible and the corresponding complete reductions.

TELECOMMUNICATIONS PRINCIPLES. By R. N. Renton. Sir Isaac Pitman and Sons, Ltd., London, England, 1950. 450 pages, illustrations, diagrams, charts, tables, 10 by 7¼ inches, cloth, 37s.6d. The main purpose of this book is to describe fundamental principles underlying the practice of telegraphy, telephony and radio, with some application to practice where it seemed to be desirable or helpful. Chapters are included on electric machinery, meters and measurements, electronics, and the principles of sound. Units and symbols are listed and defined in appendixes. The treatment is comprehensive and designed to fit certain British examinations in telecommunications engineering.

TELEPHONY, Volume II. Automatic Exchange Systems. By J. Atkinson. Sir Isaac Pitman and Sons, Ltd., London, England, 1950. 872 pages, illustrations, diagrams, charts, tables, 10 by 7½ inches, cloth, 50s. Written primarily for students of telephony and for those engaged in the construction or maintenance of telephone equipment, this book, the second of a 2-volume set, is devoted to the theory and practice of automatic switching. The facilities, switching principles, and circuit descriptions relate to the current practice used in countries where standard British automatic exchange equipment is used. Brief descriptions also are given of the more common automatic switching systems used elsewhere. Problems follow each chapter, and their answers are given in the Appendix. Traffic capacity tables and a bibliography also are included.

TIME BASES (Scanning Generators), Their Design and Development with Notes on the Cathode Ray Tube. By O. S. Puckle. Second edition revised. John Wiley and Sons, New York, N. Y., 1951. 387 pages, illustrations, diagrams, charts, tables, 8¾ by 5½ inches, $5.00. This book is devoted to the principles of design, construction, testing, and applications of scanning generators. This second edition contains an additional 150 pages covering significant wartime and postwar developments. A new chapter is added on Miller-capacitance time bases. Additions and revisions have been made in nearly every section. There now are eight appendages on specialized aspects and 18 useful tables of data.

TRANSFORMERS. By F. C. Connelly. Sir Isaac Pitman and Sons, Ltd., London, England; Pitman Publishing Corporation, New York, N. Y., 1950. 490 pages, illustrations, diagrams, charts, tables, 8¾ by 5½ inches, cloth, $7.50; 35s. This book is intended to meet the needs of laboratory workers, designers, and users of transformers in the light electrical industries. It discusses the principles and design of transformers required in line and radio communication, radio-frequency heating, electronics, portable machine tools, electromedical equipment, illumination, and measuring apparatus. The early chapters are devoted to small power transformers. The various types of audio-frequency transformers are then considered. A basic knowledge of magnetism, electricity, and calculus is assumed.

TRANSIENT ANALYSIS IN ELECTRICAL ENGINEERING. By S. Fich. Prentice-Hall, New York, N.Y., 1951. 306 pages, diagrams, charts, 8¾ by 5¾ inches, cloth, $7.35. This book extends the usual treatment of transient analysis in electrical engineering to include modern operational methods without eliminating the presentation of classical theory. Prerequisites are mathematics through the calculus, college physics, and steady-state circuit theory. A-c circuits can be studied simultaneously with this text. Problems for student solution are placed throughout the text.

ULTRASONICS. By P. Vigoureux. John Wiley and Sons, New York, N.Y., 1951. 163 pages, illustrations, diagrams, charts, tables, 10 by 6 inches, linen, $4.00. This book serves as an introduction to the technique and to the simpler aspects of the theory of propagation of ultrasonics in fluids. The general principles of apparatus and of experimental procedures are stressed rather than details. The theoretical treatment is kept as simple as possible. References to the literature published since January 1, 1939, are given in the 13-page bibliography.

WORLD RESOURCES AND INDUSTRIES. By E. W. Zimmermann. Revised edition. Harper and Brothers, New York, N.Y., 1951. 832 pages, illustrations, diagrams, charts, maps, tables, 10½ by 7¼ inches, linen, $7.50. This comprehensive book provides a functional appraisal of the availability of agricultural and industrial materials. The section on industrial resources gives specific information and statistics on various groups of materials and products of which a few are coal, petroleum, natural gas, electricity, iron and steel, copper, light metals, and chemicals. Conservation and adequacy of resources are considered. Many bibliographical references are included.

ZEIT- UND KURZZEITMESSUNGEN MIT ELEKTRONENSTRAHL-OSZILLOGRAPHEN. By P. E. Klein. Weidmannsche Verlagsbuchhandlung, Berlin, Germany, 1949. 60 pages, illustrations, diagrams, charts, tables, 9½ by 6¾ inches, paper, 3.90 D.M. A supplement to the author's book on electron beams and their applications, this book is concerned with time and short-time measurements by means of the cathode-ray oscillograph. It considers measuring procedures using polar or circular co-ordinates for processes which can be followed by means of an oscilloscope.

PAMPHLETS • • • • •

The following recently issued pamphlets may be of interest to readers of "Electrical Engineering." All inquiries should be addressed to the issuers.

Flowmeter Installations, Seal, and Condensate Chambers. This recommended practice has been prepared as part of the service of the Instrument Society of America toward a goal of uniformity in the field of instrumentation. Head-type fluid meter installations will be simplified by the adoption of uniform practices in the fabrication of their seal and condensate chambers. This uniformity pertains to the over-all dimensions, general arrangement, and location of connections, and the minimum sealing volume required by conventional meters. Pursuant to the adoption of the recommendations contained in this publication, all similar types of seal and condensate chambers would be interchangeable with respect to installation dimensions, regardless of their source of supply. Illustrated. Copies are available for 50 cents a copy from the Instrument Society of America, National Office, 921 Ridge Avenue, Pittsburgh 12, Pa.

Flashing of D-C Machines Caused by Short Circuits. A by-product of research to develop faster submarines may be a better electric motor for automobile starters and for powering the machinery of industry. To produce faster submarines requires more power output from d-c electric motors of a given size than is currently practical. One of the limiting factors in size reduction is flashover effect. The report gives an analysis of the physical phenomena underlying flashover. More horsepower per cubic inch of d-c motor is therefore in prospect. 50 cents per copy. Available from the Office of Technical Services, United States Department of Commerce, Washington 25, D. C.

Chemical Spectroscopy. In this 1950 American Society for Testing Materials' Edgar Marburg Lecture by Dr. W. R. Brode, the development and use of spectroscopic methods in analytical control is discussed. The use of both emission spectra and absorption spectra procedures are outlined and the method limitations indicated. Part of the lecture is devoted to the field of emission spectroscopy, including the development of rapid analysis procedures and the recent advance in photoelectric recording instruments. Copies available at $1.35 each from American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa.

Report on the Work of the Tin Research Institute 1950. The report covers work on the study of electro-deposition of tin-alloy coatings, one of the highlights of which was the invention of a new electroplate consisting of tin and nickel; tin-zinc plating, the adoption of which is relatively new due to the shortage of other metals; corrosion tests; chemical analysis; properties of bearings; bronze; and the manufacture of electrolytic tinplate. Copies of the report are available without charge from the Tin Research Institute, Inc., 492 West Sixth Avenue, Columbus 1, Ohio.

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METAL-CLAD EQUIPMENTS with Magne-blast circuit breakers for medium capacity circuits. Factory-assembled and completely coordinated, they include circuit breakers, buses, interconnections and interlocks—all in one compact package.

METAL-ENCLOSED DUPLEX SWITCHGEAR for centralized control and metering. These complete, factory-assembled units have control and indicating equipment on the front panels and recording, regulating and protective equipment on the rear.

METAL-ENCLOSED CABLE ENTRANCE COMPARTMENTS for the local power feeders. They include cable potheads and group-operated disconnect and grounding switches which permit easy isolation of the cable during maintenance.

METAL-ENCLOSED ISOLATED-PHASE BUS for all primary connections. Designed to withstand heavy-duty, high-capacity short-circuit stresses they are completely assembled and ready to install with other components.

METAL-ENCLOSED AIR-BLAST-CIRCUIT-BREAKER CUBICLES for main power circuits. Features included phase-segregation, mechanical interlocks, and silver contact surfaces. Available also with low-oil-content circuit breakers.

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THE SUPREME BRUSH AND CONTACT MATERIAL

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- for high current density
- minimum wear
- low contact drop
- low electrical noise
- self-lubrication

for CONTACTS

- for low resistance
- non-welding character

*Graphalloy is a special silver-impregnated graphite

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INDUSTRIAL NOTES ....

Sylvania Organizes Puerto Rican Subsidiary. Sylvania Electric Products, Inc. has organized a subsidiary, Sylvania Electric of Puerto Rico, Inc., to fabricate mica for use in radio tubes. The subsidiary has leased a 10,000-square-foot plant in Rio Piedras, a suburb of San Juan, Puerto Rico, and will start production within two months. Raymond R. Chapman has been transferred from the Parts Division of the parent company to Puerto Rico, as manager of the new plant.

Columbia Steel Establishes Tramway Division. The Columbia Steel Company, a subsidiary of the United States Steel Corporation, has established a tramway division under the management of Gordon H. Bannerman, at 141 Battery Street, San Francisco, Calif. The division was attached originally to the Trenton Iron Company, and subsequently to the American Steel and Wire Company. It has a construction record of approximately 800 tramways, cableways, and bridge jobs.

B. F. Goodrich of Canada Elects New President. Ira G. Needles, Vice-President of The B. F. Goodrich Rubber Company of Canada, Ltd., Kitchener, Ontario, has been elected company President.

Federal Appoints Graybar as Railroad Equipment Distributor. The Federal Telephone and Radio Corporation has appointed the Graybar Electric Company, Inc., as national distributor of its railroad communications and signaling equipment.

RCA Appointments. Edward M. Tuft has been made Vice-President in charge of Organization Development of the RCA Victor Division, Radio Corporation of America, and Albert F. Watters has been named to succeed Mr. Tuft as Director of Personnel.

Atomic Energy Commission Appoints Benedict. Dr. Manson Benedict has been appointed technical assistant to the general manager to organize an operations analysis staff for the United States Atomic Energy Commission. The function of this staff will be to make special analyses of technical problems involved in atomic energy development. Dr. Benedict is on leave from his position as professor of nuclear engineering at the Massachusetts Institute of Technology.

G-E Establishes Two New Divisions in the Knolls Atomic Power Laboratory. The General Electric Company has announced the appointments of Dr. Kenneth H. Kingdon as manager of a new technical division, and William H. Milton, Jr. as manager of a new operating division in the Knolls Atomic Power Laboratory near Schenectady, N. Y. The technical division, assigned to the research services division, under direction of Dr. C. G. Suits, General Electric Vice-President and Director of Research, will be responsible for fundamental and applied research functions of the laboratory; the operating division, assigned to the apparatus group, under direction of Henry V. Erben, General Electric Executive Vice-President, will be responsible for operating functions including, engineering, manufacturing, legal, and financial.

General Radio Expands Plant. The General Radio Company is starting construction of a new plant in Concord, Mass.

Combes Made Chief Engineer at Bendix. R. M. Combes has been named chief engineer of the development laboratories of the Pacific Division, Bendix Aviation Corporation.

Duro-Test Purchases Color Lighting Corporation. The Duro-Test Corporation, manufacturers of incandescent lamps, fluorescent lamps and fixtures, has purchased the Color Lighting Corporation, manufacturers of Rollo-Color lighting products. Terms of the sale include all the company's patents and patent applications. James L. Cox has been made President of the subsidiary company, and Rollow Williams, formerly President of the Color Lighting Corporation, has been made general sales manager.

Brooks and Perkins to Build New Magnesium Rolling Mill. Equipment has been purchased and contracts awarded for the first building of a new Brooks and Perkins, Inc., plant in the northwest suburban area of Detroit, Mich. This will be a jobbing-type mill to roll magnesium sheet from slabs. Construction will provide for 25-ton travelling cranes in the mill building, and a complete melting and casting department for making rolling slabs. Ownership and operation of its own rolling mill will bring about important economies and control factors for the company, as well as eliminate delays caused by the short supply of magnesium sheet.

Sierra Electric Purchases McDonald Manufacturing. The newly formed Sierra Electric and Manufacturing Company has acquired the McDonald Manufacturing Company. No changes in personnel or other arrangements are contemplated.

Dr. Getting Elected Vice-President of Raytheon. Dr. Ivan A. Getting, formerly professor of electrical engineering at Massachusetts Institute of Technology, has been elected a Vice-President, Engineering and Research, of the Raytheon Manufacturing Company. An outstanding authority on radar, Dr. Getting has held the post of Chief Scientist of the United States Air Force for the past year.

Wheelco Establishes Canadian Affiliate. The Canadian operations of the Wheelco Instruments Company will now be handled by their new Canadian subsidiary, Wheelco

(*Continued on page 23A*)

(*Continued from page 18A*)

Instruments of Canada, Ltd., 601 Merton Street, Toronto 12, Canada. Corporate officers are R. A. Schoenfeld, President, Francis Veaupre, Vice-President-Secretary, E. J. Stevenson, Vice-President-Treasurer.

Haydon Company Purchased by North American Philips. The capital stock of The A. W. Haydon Company has been purchased by The North American Philips Company, Inc. The Haydon Company will operate as a division, with no changes in manufacture, personnel, or operations.

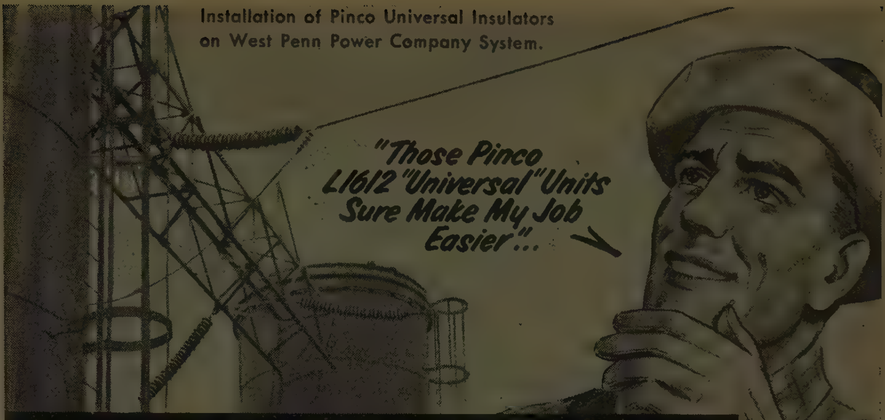
Du Mont Names Sales Representative. F. A. Dougherty, who heads his own organization at 100 Woodrow Avenue, Bedford, Ohio, has been named sales representative for the cathode-ray tube division of Allen B. Du Mont Laboratories, Inc. Mr. Dougherty's territory will include West Virginia, western Pennsylvania, and Ohio, with the exception of the city of Cincinnati.

Kaiser Transfers Sales Offices. Product sales offices of Kaiser Aluminum and Chemical Sales, Inc., for electrical conductor and rod, and bar and wire have been transferred to the company's general sales offices in the Palmolive Building, 919 North Michigan Avenue, Chicago, Ill. They had been located at the Kaiser plant in Newark, Ohio.

NEW PRODUCTS • •

Butyl-Molded Outdoor-Indoor Current Transformers. Introduced two years ago for indoor current transformers, the butyl-molding process has now been applied to an entirely new line, developed for both indoor and outdoor application. Announced by the Meter and Instrument Department of the General Electric Company, Schenectady, N. Y., these 600-volt transformers can be used on single-phase and on polyphase circuits. By using butyl, expensive porcelain and metal cases are eliminated, the molded insulation permits compact designs meeting standard mounting dimensions for indoor applications, and the transformer is completely waterproof for outdoor service. First of the new line is type *JKP-O*, a 600-volt window-type current transformer with primary ratings of 200, 400, and 600 amperes. It is designed to carry 200 per cent of rated primary current continuously. A new method was developed to seal the butyl to the protruding metal parts of the transformer to insure against moisture seepage. After the butyl is fully cured, the transformer emerges practically complete, requiring only the removal of excess molding flash, and the addition of secondary hardware and nameplate. Permanent raised polarity markers are painted white and are an integral part of the transformer. Any further information may be obtained from the company.

(*Continued on page 28A*)


Installation of Pinco Universal Insulators on West Penn Power Company System.
"Those Pinco L1612 "Universal" Units Sure Make My Job Easier"...

Competitive Tests . . . Service Records Prove Pinco L 1612 "Universal" Insulators Perform Better, Longer . . . Cost Less to Service!

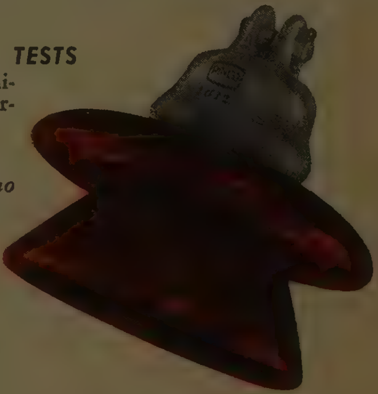
We're mighty proud of the results of the laboratory tests which proved the superiority of the Pinco L 1612. But we were not entirely surprised by the outcome, because service records over a period of *twenty years* of continuous operation back up these findings . . . records which prove that thousands of these Pinco L 1612 Units have been meeting their job requirements 100% in areas where excessive insulator contamination is an operational hazard. Certainly such a record of *trouble-free* performance proves that they're "right" where it counts . . . "right on the job!"

So when you have a tough job for insulators calling for L 1612 characteristics . . . put up Pinco *to be sure!*

IN COMPETITIVE "FOG OPERATION" TESTS

by a Western Power Company, Pinco "Universal" Insulator No. L 1612 proved its superiority by rating:

FIRST on "Fog arc over".
FIRST on sustained voltage "in fog" producing *no* arc over.
FIRST on sustained voltage "in direct spray" producing *no* arc over.
FIRST on both self-cleaning and manual cleaning characteristics.
SECOND on "sluice arc over".
EXCELLENT on radio interference characteristics.



Pinco L1612 & L1925 Features

1. Leakage distance of 17 inches.
2. Outside petticoats, shielded above by bell; below by hood.
3. Long, tapered hood is self-cleaning; acts as spatter-baffle to clean petticoats.
4. In strings, interior of hood is shielded by unit below—protected against contamination thus reducing manual cleaning requirements to a minimum.

See Page 70, Pinco Catalog No. 49 for complete electrical and mechanical characteristics.

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PINCO INSULATORS

Suspension Insulators . . . Switch and Bus Insulators . . . Distribution Clamps . . . Distribution Pin Types and Guy Strains . . . Transmission Line Fittings . . . Tree Insulators . . . Transformer and Circuit Breaker Bushings . . . One Piece and Multi-part High Voltage Pin Types . . . Suspension and Strain Clamps . . . Indoor Bus Support Porcelain . . . Lightning Arrester Porcelain.

BIDDLE
Instrument News

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NUMBER 1 OF A SERIES

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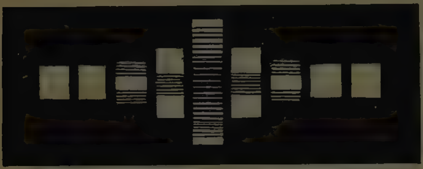
Indicate Alternating Current Frequency from 15 up to 1500 Cycles per Second

Applicable to Pulsating or Interrupted D-C as well as to A-C Supply Circuits



EASY TO READ—Vibrating reed tips form a clearly defined pattern

Here are other advantages of Frahm Resonant Reed Frequency Meters gained by the simplicity and unfailing accuracy inherent in these instruments.

- **DEPENDABLE**—permanent calibration is a natural characteristic of tuned reeds.
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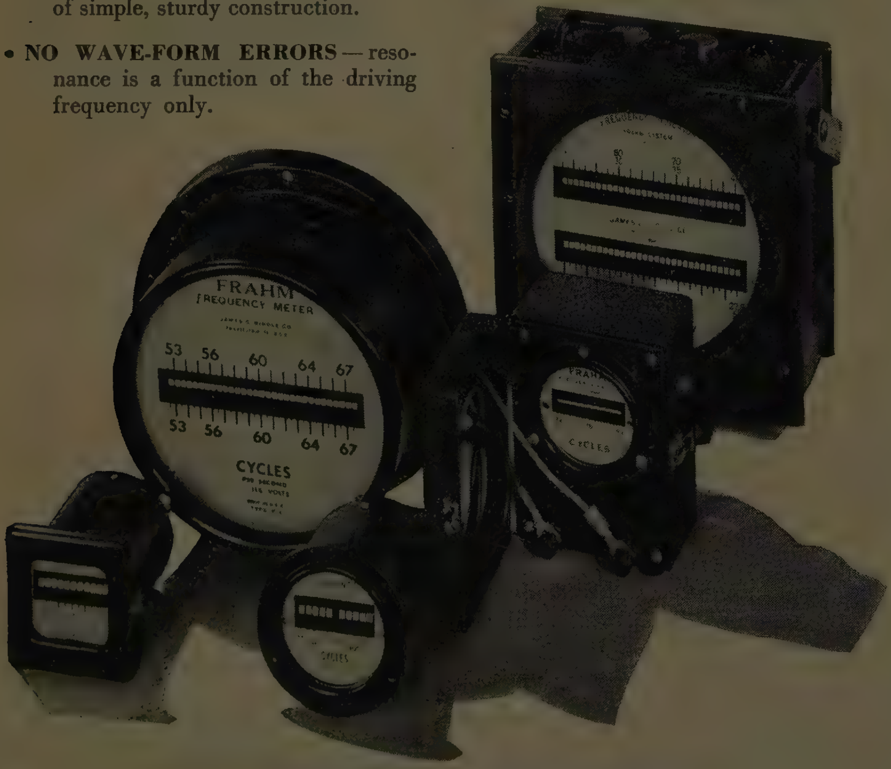
- **NO WAVE-FORM ERRORS**—resonance is a function of the driving frequency only.
- **INPUT VOLTAGE IS NOT CRITICAL**—accuracy is independent of supply voltage.
- **UNAFFECTED BY EXTERNAL FIELDS**—damping effect on natural reed frequencies is negligible.
- **INDEPENDENT OF LOAD, POWER FACTOR or PHASE SHIFTS** in supply circuit.

FRAHM Frequency Meters are available in switchboard, miniature and portable types. We invite correspondence regarding applications which require special modifications of range, method of actuating, scale graduations or other design characteristics.

We'll send you a bulletin that contains a wealth of information on this subject. Write today for Bulletin 32-EE.



(Model 1B—Battery Operated Set)

FOR LOW-RESISTANCE MEASUREMENTS BETWEEN 100 AND 10,000 MICROHMS

Megger® Low Resistance Ohmmeters in Portable Types for Field and Shop Use

Self contained battery-operated and rectifier-operated types of Megger Low Resistance Ohmmeters have just been developed. They are designed for hard routine and emergency service in measuring contact resistance, such as in circuit breakers, relays, switches, bonds, connections and joints, commutator bar-to-bar tests and the like.

These portable instruments (weight 19 lbs.), are designed for low resistance measurements in the shop and in the field. They are of moderate cost and are accurate to within 1.5% of full scale deflection.

Model 1B operates from two 4 FH dry cells mounted inside the case.

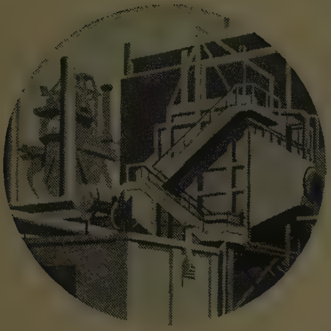
Model 1R operates from a rectifier, built inside the instrument case, for connecting to 115 volts, 50-60 cycles.

Both models have a range of from .001 to .010 ohms. These new instruments operate on the same crossed-coil ohmmeter principle as the Ducter Low-Resistance Ohmmeter, with pointer indications of resistance and no necessity for balancing or voltage adjustment. Scales have fairly uniform graduations and are approximately 3¼″ long. Anyone can operate this equipment—no special training or experience is required.

For particulars and prices write for Bulletin 24-46-EE.

War on waste!

American industry is continually searching for new ways to stop waste and increase production and efficiency. A good example of this is the Koppers-Elex electrostatic precipitator. Shown below are a few typical ways industry uses them to combat waste . . .



BLAST FURNACE GAS must be cleaned before it can be used as a fuel. Koppers-Elex electrostatic precipitators clean this gas to residuals as low as .002 grain per cubic foot.

FLUE GASES from recovery boilers in pulp mills contain valuable materials. Koppers-Elex electrostatic precipitators recover several hundred thousand dollars worth of these materials yearly.

FLY ASH from power plants and factories may drop a blanket of dust extending three to five miles. Koppers-Elex electrostatic precipitators stop this nuisance and preserve public good will.

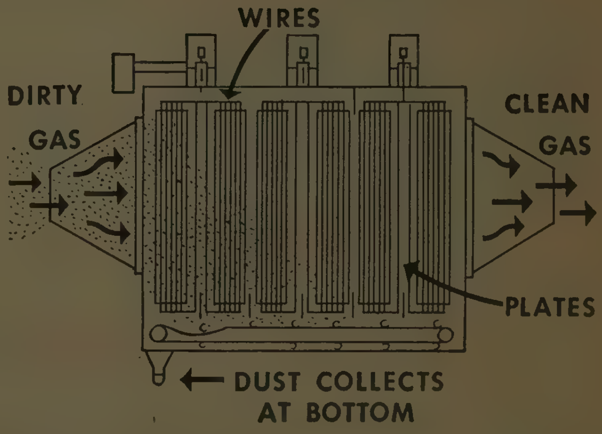
Guaranteed: All Koppers-Elex electrostatic precipitators are guaranteed to equal or better (under tests made by your own personnel) any efficiency or residual content you specify.

ENGINEERS! You should know about these six design features of Koppers-Elex electrostatic precipitators!

KOPPERS has made sweeping improvements in electrostatic precipitator design! For example, double chambers eliminate expensive by-pass systems and the resultant loss of materials during inspection or maintenance. And re-entrainment is sharply reduced because rapping is sectionalized.

Successive collection zones are separately energized to provide maximum voltage for highest collection. And because each field is, in effect, a separate precipitator, the outage of one field *does not stop* gas-cleaning action. In addition, completely enclosed and compact "package" mechanical or vacuum tube power packs simplify installation and operation.

Another exclusive Koppers feature is the drag scraper which provides continuous dust removal, eliminates plugged hoppers and prevents bothersome dust build-up. For detailed information on recovery, gas-cleaning or nuisance abatement results write today to: Koppers Company, Inc., Precipitator Dept., 330 Scott Street, Baltimore 3, Md.



If you have a gas-cleaning problem, write today to: Koppers Company, Inc., Precipitator Dept., 330 Scott St., Baltimore 3, Md.

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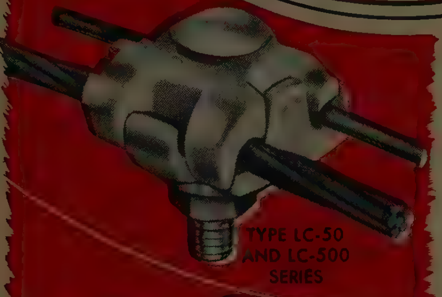
Koppers-Elex ELECTROSTATIC PRECIPITATORS

STOP CONNECTOR CORROSION FAILURES WITH



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CAST ALUMINUM
CONNECTORS
FOR
Aluminum Distribution Systems

Designed for connecting A.C.S.R. to A.C.S.R. or A.C.S.R. to copper, amerductor and copperweld conductors.

Failures of plated copper or copper alloy connectors installed on A.C.S.R. result from: high resistance destructive corrosion of contact surfaces which occurs when copper bleeds through plating causing an electrolytic action with aluminum conductor strands.

Insure against corrosion—specify Type LC—connectors with clamping members of heat treated cast aluminum alloy No. 195—conductor grooves for copper, amerductor and copperweld conductors incorporate heavy copper liners bonded to connector body by a proven special process.

Backed by many years of coordinated electrical, mechanical and metallurgical engineering knowledge and experience in the design and manufacture of cast aluminum electrical products.

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Write today for Catalog Sheets U-3, U-5 and U-6.

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AND BUS SUPPORTS
ALUMINUM SUSPENSION AND STRAIN CLAMPS

(Continued from page 23A)

Branding Machine for Vinylite Tubing. A new method for marking the identification on conductors of various electric systems has been introduced by the Ralph C. Coxhead Corporation, manufacturers of the Vari-Typer. The new marking machine is a typewriter-like device with a standard keyboard. The tubing is clamped into position in the machine and the identifying letters or numbers are typed on the tubing. The typing operation actually heat-brands the marking below the surface of the tubing, making it both indelible and permanent. A special heating device maintains the correct temperature necessary to deposit durable leaf carbon into the brand. Type is changeable; tubing from $^1/_8$-inch to $^1/_2$-inch in diameter can be branded. Type is available in special symbols and foreign languages. Further details may be obtained from the corporation at 720 Frelinghuysen Avenue, Newark 5, N. J.

Sonotest. The Radiological Corporation of America, 18 Lackawanna Plaza, Orange, N. J., has announced the availability of a new instrument for the measurement of ultrasound intensity. Produced by the Siemens-Reiniger organization, this instrument, called "Sonotest," indicates the transmitted ultrasonic power on a scale calibrated directly in watts. The average intensity in watts per square centimeter is easily obtained by dividing the integral power reading (total watts) by the transmitting area of the respective irradiation head (square centimeters). In effect, the instrument measures the mechanical sound radiation pressure. It can be used for underwater measurements and will give indications in any desired position. The range of the meter is from 0 to 60 watts. Readings are subject to an error of less than +5 per cent within the frequency range from 0.175 megacycle per second to 2.4 megacycles per second. Additional information may be obtained from the Radiological Corporation of America.

Ten-Kw Television Transmitters. RCA Victor has introduced a 10-kw very-high-frequency television transmitter. Making available facilities for wider coverage and stronger fringe-area signals, the new transmitters are high-level modulated, air-cooled equipments providing a nominal peak visual power output of 10 kw, measured at the output of the side-band filter, and a nominal peak aural power output of 5 kw. The new transmitters employ only high-gain, air-cooled tetrodes in the final amplifiers of both aural and visual units, eliminating former water-cooling methods. Grid modulation of these stages permits individual, noncritical meter tuning of all radio frequency circuits. Single-ended radio frequency circuits reduce the number of tubes and components required; fewer radio frequency stages eliminate the need for linear amplifiers in those stages; and high-level modulation requires only one broadband radio-frequency circuit for

(Continued on page 36A)

(Photo courtesy City of Seattle)

Another Way to Skin a Cat...

This spar arm carries 165-kv transmission line to make room for 230-kv line in rugged terrain . . . both Alcoa ACSR. Where terrain is difficult, there are usually "several ways to skin a cat" and easy-to-handle, lightweight Alcoa ACSR often proves the easiest—and the best.

Alcoa made the first ACSR (Aluminum Cable Steel Reinforced) . . . did the research that made mile-long spans possible, developed installation methods that made them practical.

Alcoa's storehouse of knowledge and 63 years' experience with aluminum and electricity is your assurance that you're dealing with those who can best help you solve your transmission line conductor problems.

Although the rearmament program prevents unrestricted use of aluminum, we are ready to help you with the planning required for power transmission projects.

TECHNICAL HELP—NO OBLIGATION

Write for help, advice or technical literature. Address: ALUMINUM COMPANY OF AMERICA, 2102K Gulf Bldg., Pittsburgh 19, Pennsylvania.

ALCOA ALUMINUM ®

ALCOA FIRST IN ALUMINUM FIRST IN **A·C·S·R**

Aluminum Cable Steel Reinforced

CAN CARBON BE SOLDERED TO METAL?
The answer is YES! . . . and this new Stackpole method cuts costs and adds efficiency to a lot of brush, contact and friction device applications

Now Stackpole can solder carbon brushes, contacts or friction devices directly to their metal supports!

Carbon brushes, for instance, can be silver soldered to leaf springs, thus eliminating brush holders and shunts. Carbon contacts can be soldered directly to metal arms. Carbon friction discs can be soldered directly to metal backing plates—and so on through an interesting range of possibilities. You gain all of the advantages of carbon—*without the need for costly fixtures for bolting or clamping it in place!* There are some limitations on size. Send details of your application for recommendation by Stackpole engineers.

STACKPOLE CARBON COMPANY, St. Marys, Pa.

STACKPOLE

Everything in Carbon but Diamonds

(*Continued from page 28A*)

tuning. Power line requirement is rated 208 to 230 volts, 60 cycles, 3-phase. RCA Victor, Division of the Radio Corporation of America, Camden, N. J., will supply any additional details.

Two New Lamps. A new light source, the 400-watt *J-H1* fluorescent mercury-vapor lamp, has been introduced by the Westinghouse Electric Corporation, Lamp Division, Bloomfield, N. J. The bulb of the *J-H1* has an inside coat of a phosphor that fluoresces red when activated by invisible ultraviolet light generated by the quartz arc. This tends to balance the spectrum to provide a light that is white enough for most industrial purposes. Equipped with a *BT-37* bulb with an isothermal shape that provides an even operating temperature over the entire bulb wall, the new lamp will burn in any position and can be used in existing fixtures for 400-watt mercury lamps.

Another light bulb introduced by Westinghouse is a new incandescent lamp that resembles the picture tube of a small television set. This 800-watt, 7$^{1}/_{8}$-inch maximum diameter lamp will burn an average of 1,500 hours, or about four months on a 2-shift operation. (The regular 750-watt light bulb which this new lamp should replace in many industries burns an average of 1,000 hours.) The new lamp, designated the *R-57* bulb industrial reflector, has a built-in silvery reflector on the inside of the bulb similar to a sealed beam automotive headlight, so that dirt will not reduce its efficiency.

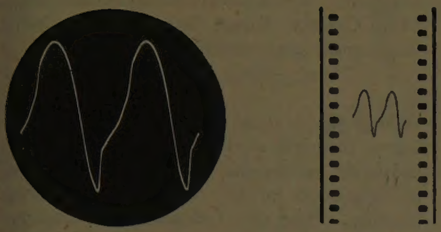
Further information on these new lamps may be obtained from Westinghouse.

Giant Teletron. The Cathode-Ray Tube Division of Allen B. Du Mont Laboratories has announced production of a 30-inch teletron, the *30BP4*, which presents a usable picture area of approximately 536 square inches. An unusual feature of the giant tube is the short over-all length (only about two inches longer than the 20-inch tube) achieved through the use of a 90-degree deflection angle. The anode is designed to operate at 20,000 volts. A single-magnet ion trap prevents ion burns. Mr. B. C. Scales, Sales Manager of the Cathode-Ray Tube Division, Allen B. Du Mont Laboratories, Inc., Clifton, N. J., will handle any inquiries.

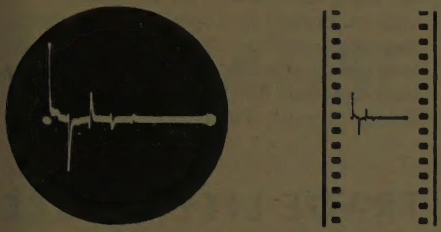
Dialing Auxiliary. Facilities for dial signaling can be added inexpensively to existing *H1* Western Electric carrier systems by use of the new type *H1-D* equipment announced by the Lenkurt Electric Company. One terminal provides full duplex carrier-frequency dial-signaling pulses at the usual rates (10 to 14 pulses per second) on frequencies not essential to the *H1* voice channels. Power is ordinarily supplied from existing equipment. The auxiliary includes stabilized vacuum-tube oscillators for the generation of signaling frequencies which are transmitted to the line under control of relays

(*Continued on page 54A*)

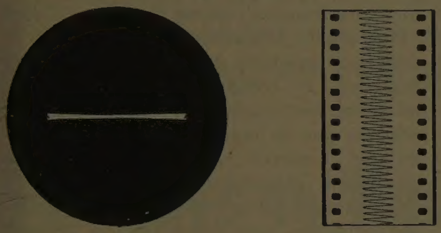
How much can you expect an oscilloscope camera to do?



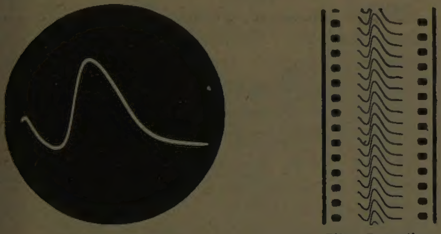
1. Single-frame photography of stationary patterns using a continuously running sweep.



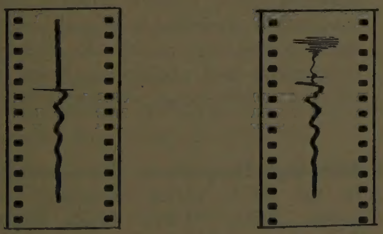
2. Single-frame photography of single transients using a single sweep.



3. Continuous-motion photography employing film motion as a time base.



4. Continuous-motion photography employing oscilloscope sweep as a time base.



5. Continuous-motion photography employing combination of film motion and oscilloscope sweep as a time base.

It's only reasonable that you should expect the oscilloscope camera you buy to record what you see on an oscilloscope screen during any period. But can it be expected to do any more? We think so.

For example, did you know that the *Fairchild Oscillo-Record Camera*—our idea of the most versatile 35-millimeter oscilloscope camera now available—can GREATLY EXTEND THE USEFULNESS OF YOUR OSCILLOSCOPE?

As you know, many non-recurring phenomena occur too rapidly to permit adequate visual study. Others occur so slowly that continuity is lost. Sometimes you have combinations of very slow-speed phenomena and occasional high-speed transients. In any one of these cases, the Fairchild Oscillo-Record Camera will take over where your eye and the oscilloscope leave off.

This extremely versatile instrument is now being used daily by many hundreds of engineers in widely divergent fields. For an idea of what it can do for you, study the five scope images and recordings illustrated at left. Each solves a particular problem.

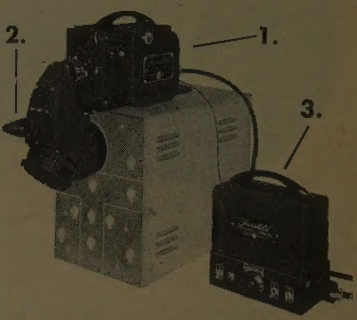
Oscillo-Record users especially like its:

CONTINUOUSLY VARIABLE SPEED CONTROL—1 in./min. to 3600 in./min.

TOP OF SCOPE MOUNTING that leaves controls easily accessible.

PROVISION FOR 3 LENGTHS OF FILM—100, 400, or 1000 feet.

For more data write *Fairchild Camera Instrument Corp., 88-06 Van Wyck Blvd., Jamaica 1, N. Y. Dept. 120-16E.*

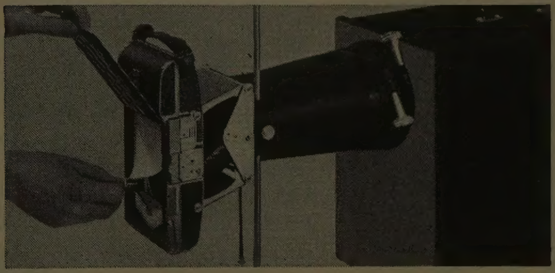


FAIRCHILD OSCILLO-RECORD CAMERA—1. camera, 2. periscope, 3. electronic control unit. *Available* accessories include external 400 and 1000 foot magazines, magazine adaptor and motor, universal mount for camera and periscope, binocular split-beam viewer.

VALUABLE RECORDS FOR IMMEDIATE EVALUATION

The Fairchild-Polaroid® Oscilloscope Camera produces a photographic print in a minute

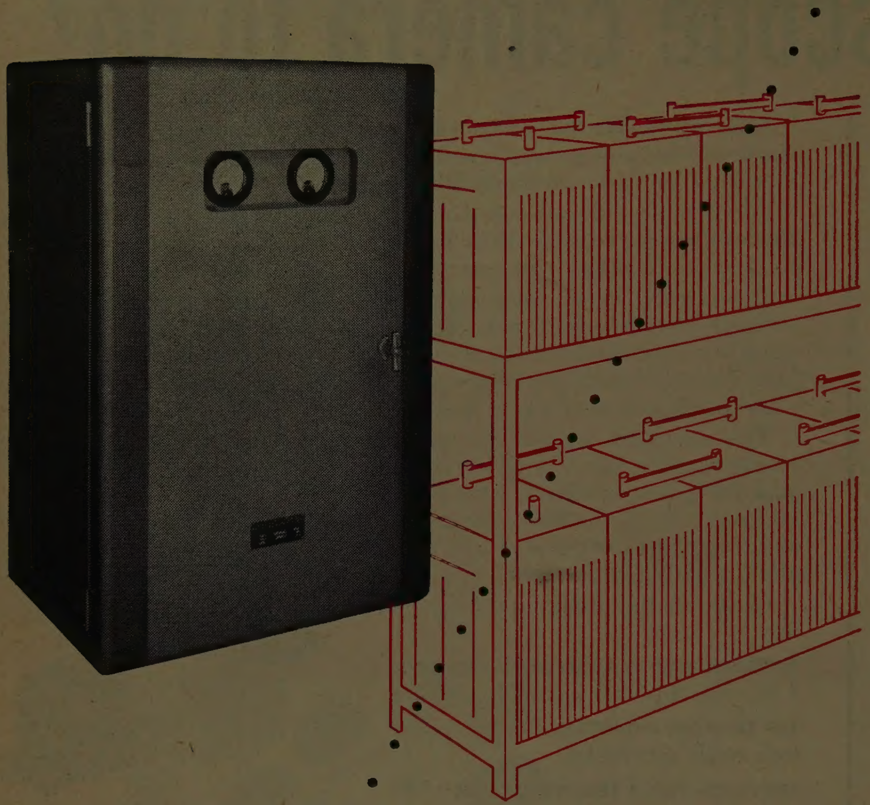
Valuable but inexpensive oscillograms for immediate evaluation; automatic one-minute processing without a darkroom; a set up time of two minutes or less—they're just three of the many advantages that are yours when you use the Fairchild-Polaroid Oscilloscope Camera. Wherever individual exposures meet your recording requirements—where you'd like to have permanent records of the traces you're now sketching or carrying in your memory, this is the camera that can bring new speed, ease and economy to your job. Prints are 3¼x4¼ and each records two traces exactly one-half life size. Write today for details.



A minute after you've pulled the tab a finished print is ready for evaluation

FAIRCHILD
OSCILLOSCOPE RECORDING CAMERAS

for LONGER battery LIFE



keep the floating voltage constant with PECO Automatic Battery Chargers

The PECO Battery Chargers accurately float the control battery of any power station or substation which has a reasonably constant switchboard load; furnishes power to the load and maintains a fully charged battery, ready for any emergency.

To provide extreme accuracy of electronic control and the exceptional reliability demanded by this type of service, Power Equipment engineers designed this PEC-626 Automatic Battery Charger by starting with the rugged components of a manual charger, then added a magnetic system for coarse voltage control and a simplified electronic system for fine voltage control.

As an illustration of the accuracy of the PECO charger, this example can be used: the DC output is sufficient to maintain 60 lead acid battery cells at 129 volts; it will also furnish power to switchboard loads within the rating of the charger, and at all times the output voltage is automatically regulated to within ± 0.5 percent, for AC line voltage fluctuations of ± 5 volts on a 230 volt circuit.

Exceptional reliability is shown by the fact that if the electronic control section should be disconnected, the magnetic control section will still automatically hold the output voltage to within ± 3 percent of nominal voltage.

Write for complete specifications today.

POWER EQUIPMENT Company

Battery Chargers ☆ Battery Eliminators ☆ D.C. Power Supply Units ☆ Regulated Exciters ☆ and other Special Communications Equipment

55 ANTOINETTE STREET DETROIT 2, MICHIGAN

(*Continued from page 36A*)

actuated by d-c signals from the terminal equipment. Bandpass filters between the *H1* terminals and their line filters restrict the voice channels to the range 4,400 to 10,750 cycles per second and release frequencies at 4,150 and 11,500 cycles per second for the signaling channels. Incoming pulses are reconverted into d-c signals to operate switchboard or dial equipment. Operations in the two directions of transmission are entirely independent. The Lenkurt Electric Company, 1105 County Road, San Carlos, Calif., will supply any additional information.

Odorout. A tiny lamp that dissipates odors through a triple output of ozone-inducing radiations has been developed by engineers of the Westinghouse lamp division. The new Odorout bulb changes odor molecules in air instantly. This occurs as ultraviolet radiations of special wavelength transform the oxygen around the lamp into ozone, an air purifier. It must be burned in a special fixture with a current-controlling device. Further information may be obtained from the Westinghouse Electric Corporation, 306 Fourth Avenue, Pittsburgh 30, Pa.

TRADE LITERATURE

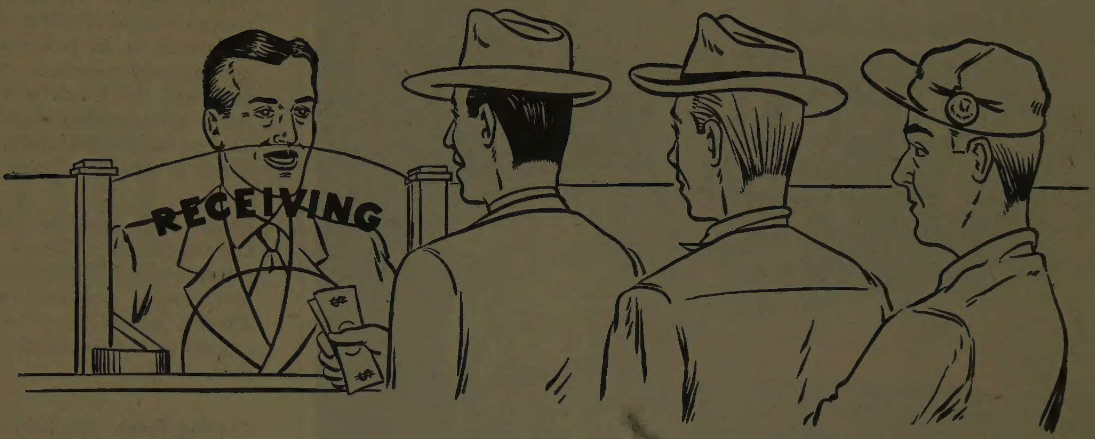
Productive Maintenance. The General Electric Company has announced a new plan to help industry get the most productivity from its existing facilities. Called "Productive Maintenance," the plan is designed primarily to assist maintenance engineers in setting up a program to minimize lost production time and forced idleness due to equipment failures. Materially, General Electric is offering a productive maintenance kit, which contains an instruction bulletin, balance sheet, outage forms, and check lists for motors, control, and other equipment. To supplement the kit, a new slide-film on the subject will be available this fall for showing through the local General Electric offices. In addition, General Electric service engineers, upon request, will assist in making a complete survey to determine existing conditions, future outages, and to guide in setting up a working spare parts control. The kit, or additional information on the program, may be obtained from the General Electric Company, Service Shop Division, Schenectady 5, N. Y.

Battery Technology. Gould-National Batteries, Inc., Trenton 7, N. J., has announced as available a 56-page edition of their pocket-size handbook of technical instructions and engineering data on the care of motive-power storage batteries.

Ultrahigh Frequency. The latest booklet in the RCA Victor electronic training series, titled "Ultra High Frequency Fundamentals," has been announced as available. The new manual has been prepared as a technical aid for ultrahigh

(*Continued on page 66A*)

Everybody Wants



—BECAUSE EVERYBODY PROFITS!

GOOD VOLTAGE REGULATION pays dividends all around. Customers get all the electricity they need. And they get full value from the power they pay for because their equipment performs better and lasts longer.

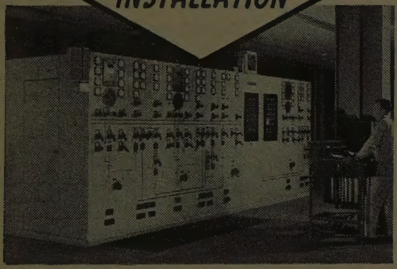
But accelerated growth is pushing peak loads near estimates made a few years ago for 1953, and regulation must be achieved in the face of expanding loads and material shortages.

Now more than ever, your experienced Allis-Chalmers representative can help you utilize the wide line of A-C equipment to solve your power distribution — and production — problems. Allis-Chalmers, Milwaukee 1, Wisconsin. A-3488

Ruptor and Regulex are Allis-Chalmers trademarks.

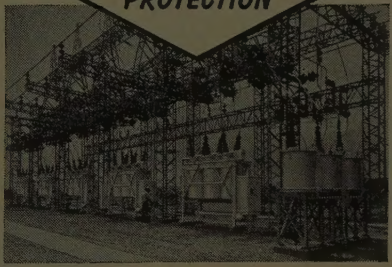
It Pays to Keep Pace with Machinery Progress

EASY INSTALLATION



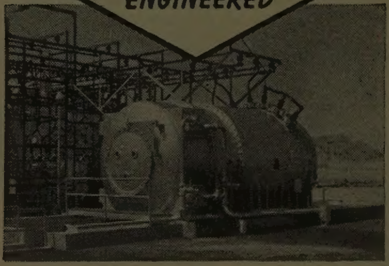
DUPLEX SWITCHBOARDS are factory assembled for economical installation. Convenient centralized secondary control for primary circuits assures good voltage regulation at the beginning of the line.

POSITIVE PROTECTION



OIL CIRCUIT BREAKERS team up *Ruptor* quick-quench interruptors with mechanically trip-free pneumatic or solenoid operators to minimize system voltage variation by prompt isolation of system faults.

CUSTOM ENGINEERED



SYNCHRONOUS CONDENSERS — used indoors or out — supply reactive kva to regulate voltage and stabilize large transmission systems. Air or hydrogen cooled. *Regulex* control adds fast response to changes.

CHALMERS

A-C
ALLIS-CHALMERS

ELECTRONS
INC.
NEWARK, N.J.
C6J/A
MANUFACTURED UNDER ONE OR MORE OF THE FOLLOWING U.S. PATENTS
LIGHT FILAMENT BEFORE APPLYING D-C LOAD

Courtesy of Bart-Messing Corporation,
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ELECTRONS INCORPORATED
127 SUSSEX AVENUE
NEWARK 4, N. J.

"The output of this 13,000 amp. Sel-Rex Selenium Rectifier is precisely controlled by three EL C6J/A thyratrons."

(*Continued from page 54A*)

frequency training and the installation, operation, and maintenance of ultrahigh frequency electronic equipment. The price is $0.75; orders may be placed with the Government Service Division, RCA Service Company, Gloucester, N. J.

Air Pollution. To show how the minute concentrations of sulfur dioxide which are of interest in air pollution surveys can be continuously measured and automatically recorded, the Leeds and Northrup Company, 4934 Stanton Avenue, Philadelphia 44, Pa., has published a folder, *ND46-91(1)*, which is available upon request.

Mica and Faradon Capacitors. The Cornell-Dubilier Electric Corporation has released a new combination 60-page mica and faradon capacitor catalogue, number *420-421*, which may be obtained upon request to the corporation at South Plainfield, N. J.

Cutting Steel. To help steel users get the most out of available steels, the United States Steel Company has prepared a 72-page booklet, "Tables of Multiple Lengths," which is designed to help minimize waste in cutting steel. The tables can be used to determine the exact size of any given number of lengths that can be cut from a longer length. Copies are available from the United States Steel Corporation, Room 4284, William Penn Place Building, Pittsburgh 30, Pa.

Selecting Engineering Irons. A new reference bulletin, compiled primarily for design engineers, presents the characteristics of modern nickel cast engineering irons as a guide to their selection. The International Nickel Company, Inc., Department EZ, 67 Wall Street, New York 5, N. Y., will supply copies upon request.

Corrosive Resistance of Copper. The results of 25 years of laboratory research and field study of the nature of corrosive attack on copper and copper alloys have been presented in a 24-page booklet, "Corrosion Resistance of Copper and Copper Alloys," Anaconda Publication *B-36*, which may be obtained upon request to The American Brass Company, Waterbury 20, Conn.

Carrier Dialing. Auxiliary equipment designed to add dial-signaling channels to existing *H-1* Western Electric carrier systems is described in a new folder, Form *H1D-P10*, available from the Lenkurt Electric Company, Inc., 1105 County Road, San Carlos, Calif.

Tin and Its Uses. The Tin Research Institute, Fraser Road, Greenford, Middlesex, England, has published a new issue of its review, "Tin and Its Uses," number 24. This review is available upon request.

Copper Weights. A new bulletin, "Copper Weights of Electrical Wires and Cables," has been announced as available from Rome Cable Corporation, Rome, N. Y.